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Technical Report ARAED-TR-95013

PALADIN LOCK VALVE HYDRAULIC TEST STAND UPGRADE AND BASELINE VALIDATION

Paul Kida and William Zepp

January 1996

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A summary of the modifications done to the lock valve hydraulic test stand to enable verification of all drawing requirements is presented in this report. The validation of stand capabilities and the establishment of a performance baseline using production lock valves to KEMP manufacture.

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INTRODUCTION

The M109 155-mm Self-Propelled Howitzer was developed between 1957 and 1963 armed with a short 26 caliber cannon. The cannon elevation was controlled by a hydraulic system which contained a lock valve (P.N. 8744652) developed for the M48 Main Battle Tank, for maintaining the cannon elevation before, during, and after weapon firing. This valve was procured under source control from either Cadillac Gage or KEMP. In 1970, the system was up-gunned with the addition of a new and longer 39 caliber cannon. The addition of the longer tube and resulting higher dynamic loads on the elevation system overloaded the physical limits of the lock valve that was being used.

A new lock valve design, physically and functionally interchangeable, but able to withstand the dynamic loading, was developed. A valve design from KEMP was successfully developed and fielded in 1985. As before, this valve was procured under source control, with the exception that KEMP was listed as the only source.

High pressure hydraulic control valves are precision components and are costly. The addition of alternative sources creates competition and reduces procurement costs. Each alternative source must meet all of the drawing requirements. To verify compliance of the drawing requirements in a timely and cost efficient manner, a test stand was used to replicate the conditions on the weapon in place of the actual system for most tests.

BACKGROUND

To reduce procurement costs of the M109 lock valve (P.N. 11784023), a competitive procurement solicitation (DAAA09-91-B-0813) was issued on 13 November 1991 for a quantity of valves. To evaluate the samples submitted for consideration under the solicitation, a hydraulic test stand to verify compliance of drawing requirements was necessary. A contract was let to Technical Data Development, Inc. (TDDI) to fabricate the stand which was delivered to the government in August 1993. The sample valves delivered by six bidders under the procurement contract were tested using the stand during the fall of 1993.

The test stand that was delivered and used was capable of testing some, but not all of the requirements. Requirements 1, 2, 3A, 3B, 4A, 4B, 5A, 6A, and 7 of table 1 and Notes 11.B.3 at 145°F and 11.B.4 of drawing 11784023 could be evaluated. However, requirements 3C through 6C of table 1 and Note 11B.3 on the drawing at -50°F could not be evaluated. In 1994, additional requirements 8A and B, 9A and B,

10A and B, 11A and B, and 12 were added to table 1 on drawing 11784023 and Note 11A and 11B on drawing 11784023 were rewritten to define the valve requirements necessitated by use in the M109A6 PALADIN variant. PM PALADIN tasked this office, Weapons Branch, Artillery and Indirect Fire Division, to modify the test stand to enable testing of all requirements.

TEST STAND MODIFICATION

The original layout of the test stand is shown schematically in figure 1. To enable testing of requirements that this configuration could not test, a series of modifications were needed.

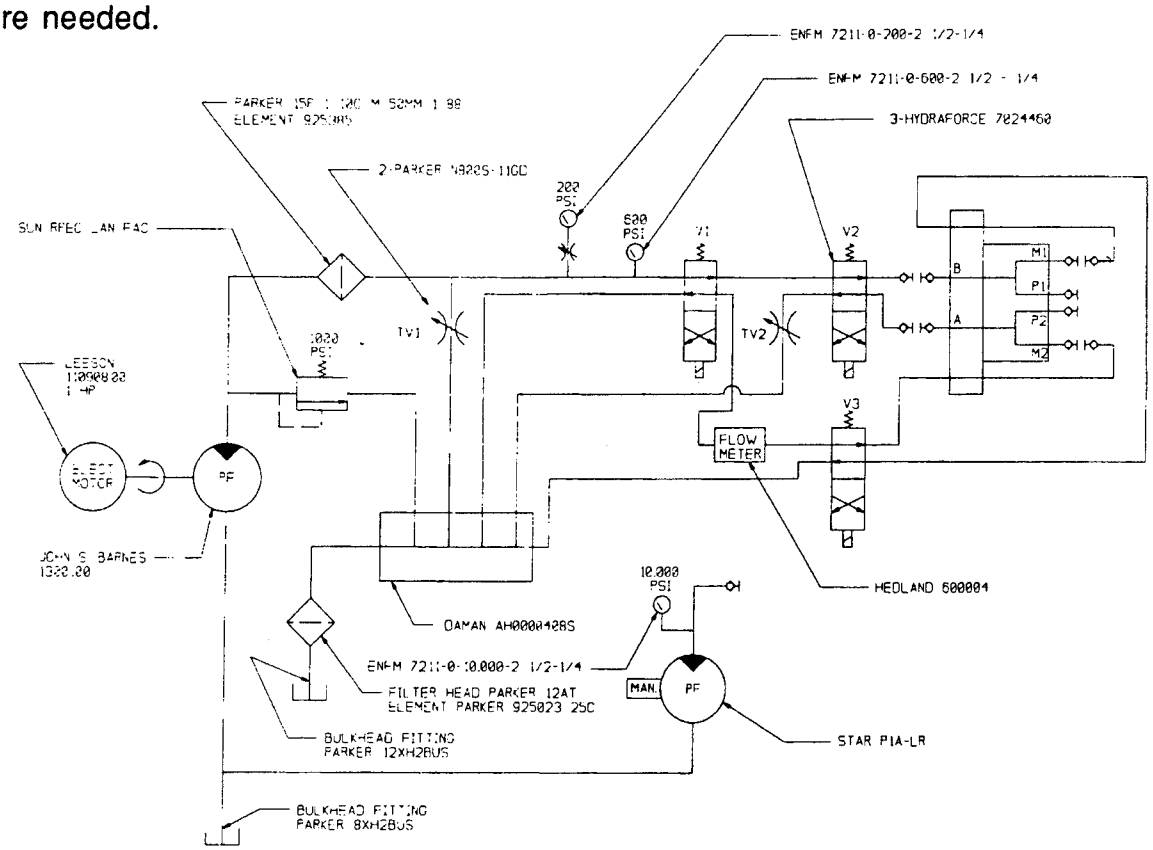

Figure 1
TDDI test stand schmatic

To verify compliance of requirements 3Cthrough 6C and 12 of table 1 of drawing 11784023, a higher pressure and viscosity capacity pump/motor assembly was needed. The originally installed pump/motor produced insufficient pressure under ambient conditions and was totally inadequate to meet test flow requirements at -50°F. After consulting with pump suppliers, a new gear pump driven by a 7.5 hp motor was determined to meet pressure and temperature requirements. This pump/motor assembly replaced the original pump/motor assembly.

Requirements 8A and B, 9A and B, and & B, and 11A and B on the drawing all need an independent second hydraulic power source. The tests demanded a constant pressure be applied to one port while the pressure applied to a different port was increased until flow through the valve was evident. The original pump/motor assembly was incorporated into the modified test stand to provide this capability.

The requirement in Note 11B.6 on the drawing to test at the revised upper temperature extreme of 250°F was satisfied by the addition of electric heater elements in the reservoir.

To perform the tests required at the low temperature extreme of -50°F, several modifications were required. The pump/motor had to be replaced to meet the viscosity at that temperature as mentioned earlier. The valve stand was made detachable to allow remote placement within a climatic cell. A hose bundle was provided to connect the valve stand, when in the climatic chamber, to the test stand that remains outside the chamber; and a refrigeration coil system was provided to maintain oil temperature.

The resulting test stand configuration is depicted in figure 2.

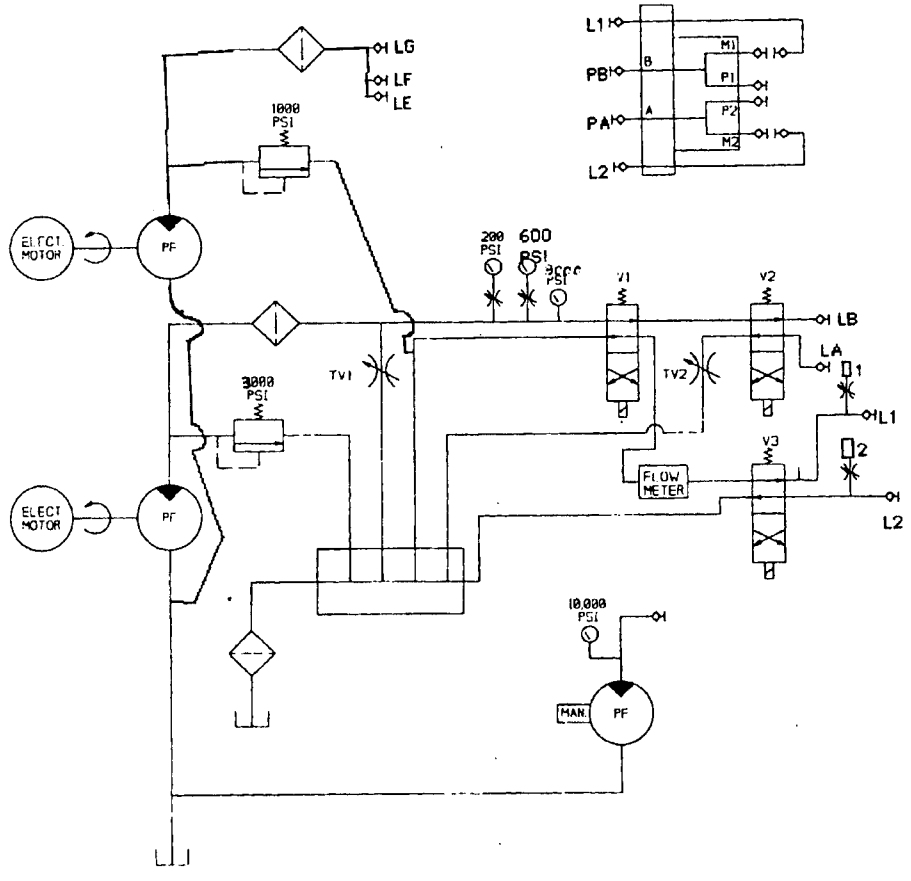

Figure 2
Test stand configuration

SYSTEM VERIFICATION

The modified test stand was initially pressure tested to 3,000 psi to verify system integrity. This was followed by executing each individual test called out using a KEMP lock valve with a known history, free of any problems, and that had been used during the previous acceptance testing during the fall of 1993. Each test was successfully performed with the modified stand.

VALVE TEST PROCEDURE

The procedure followed while conducting the First Article Test called out in the Quality Assurance Provisions of drawing 11784023 is provided in appendix A. This procedure is based upon the original test stand operating instructions provided with the original test stand by TDDI and modified to test all requirements.

As required by the First Article Test requirement stated in the Quality Assurance Provisions of drawing 11784023 and the valve cleanliness requirement stated on said drawing, a Procedural Plan was developed to insure compliance. This plan is provided in appendix B. Functional testing and endurance testing were conducted under all aspects of this plan within the clean room located in Building 3150. The climatic and on-weapon tests could not be conducted within a similar environment due to the size and location of the required environmental test cells. During these tests, precautions were taken to prevent exposure to contaminants while valves were changed and lines broken. Oil samples were taken throughout testing to verify compliance.

KEMP VALVE BASELINE PERFORMANCE

A sample of three unissued lock valves were obtained from Letterkenny Army Depot in their unopened original packaging. These valves were subjected to the test procedure described previously. Results of the subtests are presented in table 1 and appendix C. To aid in test summary, passing a requirement was scored a 1. Failing a requirement, but with the value within measurement accuracy uncertainty, was scored .9 or .8. All other failures were scored as 0.

Table 1
Test data

				REQ	SAMPLE					
FUNCT TEST					KEMP1	PASS /FAIL	KEMP2	PASS /FAIL	KEMP3	PASS /FAIL
		START DATE:			7/24/95		7/24/95		7/24/95	
		START TIME:			13:37		7:50		9:40	
	TEST 1									
		P A LEAKAGE	Y/N	N	N	1	N	1	N	1
		P B LEAKAGE	Y/N	N	N	1	N	1	N	1
	TEST 2									
		PORT M1								
			FLOW (CC)		6.5		7.5		22	
			TIME (MIN)		5		5		5	
			FLOW	1 < X <	1.3	1	1.5	1	4.4	1

Table 1
(cont)

			(CC/MIN)	6						
		PORT P1								
			FLOW (CC)		5.5		6.5		22	
			TIME (MIN)		6		5		5	
			FLOW (CC/MIN)	1 < X < 6	.92	.9	1.3	1	4.4	1
		PORT M2								
			FLOW (CC)		4		5		7	
			TIME(MIN)		5		5		5	
			FLOW (CC/MIN)	1 < X < 6	.8	.8	1.0	1	1.4	1
		PORT P2								
			FLOW (CC)		5		5.5		29	
			TIME (MIN)		5		5		5.05	
			FLOW (CC/MIN)	1 < X < 6	1	1	1.1	1	5.74	1
	TEST 3									
		OIL TEMP (DEG F)			90		86		(NR)	
		ON PRES (PSI)		125 - 170	155	1	160	1	165	1
		FLOW (GPM)		2.9 MIN	3.14	1	2.9/3.25 *	1	3.08	1
		AT ? PRES (PSI)		370 MAX	370	1	370	1	370	1
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	144	1	140	1	142	1
	TEST 4									
		OIL TEMP (DEG F)			90		86		108	
		ON PRES (PSI)		125 - 170	155	1	158	1	165	1
		FLOW (GPM)		2.9 MIN	3.19	1	3.25	1	2.7/3.14*	1
		AT ? PRES (PSI)		370 MAX	370	1	370	1	370	1
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	141	1	148	1	140	1
	TEST 5									
		OIL TEMP (DEG F)			93		89		108	
		ON PRES (PSI)		125 - 170	155	1	164	1	168	1
		FLOW (GPM)		2.9 MIN	3.19	1	3.19	1	3.31	1

Table 1
(cont)

		AT ? PRES (PSI)		370 MAX	370	1	370	1	370	1
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	130	1	136	1	130	1
	TEST 6									
		OIL TEMP (DEG F)			93		88		110	
		ON PRES (PSI)		125 - 170	157	1	160	1	165	1
		FLOW (GPM)		2.9 MIN	3.19	1	3.25	1	3.31	1
		AT ? PRES (PSI)		370 MAX	370	1	370	1	370	1
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	130	1	138	1	147	1
	TEST 7									
		PORT A (DROPS/4 MIN)		3	0	1	2	1	0	1
		PORT B (DROPS/4 MIN)		3	.5	1	0	1	0	1
	TEST 8									
		PORT P1 ON PRES (PSI)		325 - 370	355	1	360	1	355	1
		PORT P2 ON PRES (PSI)		325 - 370	360	1	360	1	360	1
	TEST 9									
		PORT M1 ON PRES (PSI)		125 - 170	190	0	190	0	195	0
		PORT M2 ON PRES (PSI)		125 - 170	190	0	190	0	190	0
	TEST 10									
		PORT P1 ON PRES (PSI)		325 - 370	350	1	365	1	360	1
		PORT P2 ON PRES (PSI)		325 - 370	360	1	360	1	360	1
	TEST 11									
		PORT M1 ON PRES (PSI)		125 - 170	195	0	190	0	200	0
		PORT M2 ON PRES (PSI)		125 - 170	200	0	190	0	200	0
	TEST 12									
		TOTAL LEAK (DROPS)			11		66		20	

Table 1
(cont)

		TIME (MIN)			2		4		2	
		RATE (DROPS/MIN)		4 MIN	5.5	1	16.5	1	10	1
COLD TEST										
		START DATE			8/14/95		8/14/95		8/14/95	
		START TIME:			(NR)		15:52		15:26	
		CHAMBER TEMP (DEG F)			-50		-50		-50	
		OIL TEMP (DEG F)			-50		-50		-50	
	TEST 3									
		ON PRES (PSI)		125 - 170	177	.9	185	.8	178	.9
	TEST 4									
		ON PRES (PSI)		125 - 170	174	.9	182	.8	172	1
	TEST 5									
		ON PRES (PSI)		125 - 170	170	1	182	.8	188	.8
	TEST 6									
		ON PRES (PSI)		125 - 170	175	.9	184	.8	188	.8
HOT TEST										
		TEST DATE:			8/1/95		8/1/95		8/1/95	
		START OIL TEMP (DEG F)			252		266		251	
	TEST 3									
		OIL TEMP (DEG F)			253		248		259	
		ON PRES (PSI)		125 - 170	140	1	150	1	148	1
		FLOW (GPM)		NA	2.5		2.4		2.1	
		AT ? PRES (PSI)		NA	370		370		370	
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	135	1	> 50	0	> 50	0
		OIL TEMP (DEG F)			258		(NR)		254	

Table 1
(cont)

	TEST 4									
		OIL TEMP (DEG F)			258				257	
		ON PRES (PSI)		125 - 170	137	1	155	1	150	1
		FLOW (GPM)		NA	2.7		2.2		1.9	
		AT ? PRES (PSI)		NA	370		370		370	
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	122	1	> 50	0	> 50	0
		OIL TEMP (DEG F)			272		(NR)		248	
	TEST 5									
		OIL TEMP (DEG F)			272		(NR)		248	
		ON PRES (PSI)		125 - 170	140	1	145	1	150	1
		FLOW (GPM)		NA	2.7		2.8		2.7	
		AT ? PRES (PSI)		NA	370		370		370	
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	108	1	122	1	> 50	0
	TEST 6									
		OIL TEMP (DEG F)			267		(NR)		(NR)	
		ON PRES (PSI)		125 - 170	140	1	142	1	155	1
		FLOW (GPM)		NA	2.7		2.9		2.3	
		AT ? PRES (PSI)		NA	370		370		370	
		950 PSI Y/N		Y	Y	1	Y	1	Y	1
		OFF PRES (PSI)		ON P +/- 50	112	1	118	1	> 50	0
	TEST 7									
		OIL TEMP (DEG F)			262		268		253	
		PORT A (DROPS/4 MIN)		3	29	0	39	0	22	0
		PORT B (DROPS/4 MIN)		3	40	0	50	0	0	1
		TEST END DATE:			8/1/95		8/1/95		8/1/95	
		FINAL OIL TEMP(DEG F)			260		(NR)		(NR)	
SHOCK										
	X	30 G / 11 msec			30/10	1	30/10	1	30/10	1

Table 1
(cont)

		55 G / 2.5msec			54/2.4	1	54/2.4	1	54/2.4	1
		70 G/0.5 msec			72/1.2	1	72/1.2	1	72/1.2	1
	Y	30 G / 11 msec			32/10	1	32/10	1	32/10	1
		55 G / 2.5msec			51/2.5	1	51/2.5	1	51/2.5	1
		70 G/0.5 msec			75/1	1	75/1	1	75/1	1
	Z	30 G / 11 msec			32/10	1	32/10	1	32/10	1
		55 G / 2.5msec			60/2	1	60/2	1	60/2	1
		70 G/0.5 msec			66/1.2	1	66/1.2	1	66/1.2	1
VIBRATION										
	X	5-25 Hz / +/- 1.5G			5.5-25 /1.5	1	5.5-25 /1.5	1	5.5-25 /1.5	1
		25-50 Hz / .03 IN			25-50 /.03	1	25-50 /.03	1	25-50 /.03	1
		50-500 Hz / +/- 5 G			50-500/5	1	50-500 /5	1	50-500 /5	1
	Y	5-25 Hz / +/- 1.5G			5.5-25 /1.5	1	5.5-25 /1.5	1	5.5-25 /1.5	1
		25-50 Hz / .03 IN			25-50 /.03	1	25-50 /.03	1	25-50 /.03	1
		50-500 Hz / +/- 5 G			50-500/5	1	50-500 /5	1	50-500 /5	1
	Z	5-25 Hz / +/- 1.5G			5.5-25 /1.5	1	5.5-25 /1.5	1	5.5-25 /1.5	1
		25-50 Hz / .03 IN			25-50 /.03	1	25-50 /.03	1	25-50 /.03	1
		50-500 Hz / +/- 5 G			50-500/5	1	50-500 /5	1	50-500 /5	1
ENDURANCE										
		CYCLES SUCCESSFUL			18000	1	18000	1	18000	1
ON-WEAP										
	GUN	DROOP								
		CHANGE IN EL (MILS)			1.2		.6		.3	
		TIME DURATION (HOURS)			1		1		1	
		DROOP RATE (MIL/HOUR)			1.2	1	.6	1	.3	1
GUN CYCLE TIME										
		TIME 0 - MAX EL (SEC)		11 MAX	9.25	1	8.87	1	9.3	1
		TIME MAX EL - 0 (SEC)		11 MAX	9.44	1	9.25	1	9.53	1

Table 1
(cont)

		TIME 0 - MAX EL (SEC)		11 MAX	8.75	1	8.84	1	8.91	1
		TIME MAX EL - 0 (SEC)		11 MAX	9.35	1	9.06	1	9.29	1
		TIME 0 - MAX EL (SEC)		11 MAX	8.56	1	8.75	1	8.9	1
		TIME MAX EL - 0 (SEC)		11 MAX	9.22	1	9.07	1	9.25	1
GUN VEL AT 533 MILS										
		EL RATE OSCILATION	(Y / N)	N	N	1	N	1	N	1
		RATE INFLECTION POINT	(Y / N)	N	Y	0	Y	0	Y	0
		MIN ELDEP RATE		130 MIL/SEC	136.3	1	135.9	1	133.9	1
		MANUAL HANDLE MOTION	(Y / N)	N	N	1	N	1	N	1
				TOTALS (85max)		77.4		75.2		74.5
				TEST -> PASS/ FAIL		FAIL		FAIL		FAIL
SAMPLE IDENT:		KEMP1								
		DAAE2095C0090								
		SN: W1952FT								
		KEMP2								
		DAAE2095C0090								
		SN: W1955FT								
		KEMP3								
		DAAE2095C0090								
		SN: W1953FT								

NOTE:

(NR) - Data Element not recorded.

* - Indicates (initial value recorded during initial run of test) / (second value recorded during second run of test following applying a high pressure to either one side or the other of the spool involved)

During the cold test phase of the climatic test, it was found that -50°F oil could not be supplied in quantity to the valve under test. The valve, valve stand, and the oil in and around the immediate vicinity of the valve stand, was kept within a climatic cell maintained at -50° to -55°F, and could be kept at that temperature. Once flow was initiated, oil at an elevated temperature would flow through the valve. This warmer fluid would flow through the valve and raise the temperature of the valve under test. Therefore, only part "a" of tests 3 through 6 were executed, measurement of the required pressure to open the valve for each control port. The measurement of the off pressure requires extended flow of oil through the valve which would have invalidated results and was not attempted. This lack of verification of requirements was in no way held against the sample valves in evaluation of passing the test.

CONCLUSIONS

The lock valve test stand was successfully modified to enable the performance of the tests required to verify all drawing requirements. Due to environmental equipment constraints, the performance of flow measurements at the extreme cold condition could not be performed. Using a heat exchanger upstream of the test valve and down stream of the pump and valving would provide the required -50°F fluid needed to perform the necessary flow tests.

While performing the baseline testing of the three KEMP valves, no major failures of requirements were observed. Failure to meet some requirements were, however, observed. In the Functional test, two instances of spool sticking occured. In one instance, the valve passed for both measurements. In the other instance, the valve failed due to slightly low flow at the first measurement and passed for the second measurement. All three valves failed the 500 psi back pressure tests by requiring 190 to 200 psi to open the spool where 170 psi maximum is the requirement. In the climatic test there were slight problems. During the cold test phase, all measured flow on pressure measurements were slightly high, 175 to 188 psi versus 170 psi maximum. During the hot test phase, valves W1955FT and W1953FT exhibited flow off pressure measurements that were less than the on pressure minus 50 psi that was required. For both valves, pressures of less than 50 psi were recorded where 98 to 105 psi would have been required. Also, during the hot test phase, all valves exhibited excessive leakage. All valves performed as required for the on-weapon and endurance tests.

RECOMMENDATIONS

Based upon the findings of the baseline testing, it is recommended that several requirements as called out on the drawing 11784023 be adjusted. These adjustments reflect actual measurements under the required circumstances of KEMP production valves that perform as needed when installed into a PALADIN weapon. The recommended adjustments are as follows:

Change Note 11.b.6 to read:

" 6. OPERATING TEMPERATURE: -50 DEG F TO 250 DEG F. TABLE I REQUIREMENTS 3A (125 - 190 PSI AT -50 DEG F), 3C (+50/-140 PSI AT 250 DEG F) , 4A (125 - 190 PSI AT -50 DEG F), 4C (+50/-140 PSI AT 250 DEG F), 5A (125 - 190 PSI AT -50 DEG F), 5C (+50/-140 PSI AT 250 DEG F), 6A (125 - 190 PSI AT -50 DEG F), AND 6C (+50/-140 PSI AT 250 DEG F). "

To reflect actual performance under extreme conditions of properly functioning valves.

Change Table I, Requirement No. 9 under " Apply Pressure Of " to read:

" 125 to 200 "

Increase from 170 to 200 psi will not affect on-weapon performance.

Delete from Note 11.B.3:

" A PLOT OF THE WEAPON SPEED VERSES HANDLE POSITION (IN DEGREES) SHALL SHOW NO INFLECTION POINTS. "

All three valves exhibited inflection points and all three passed all other on-weapon requirements.

APPENDIX A

TEST PLAN AND PROCEDURES

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3 Aug. 1995

Qualification Test Plan
For Lock Valve, PN 11784023

1. Material for test:

A. Provided by test agency:

1	Valve Test Stand
1	Climatic Chamber
1	Oil Chiller System
	Oil, Hydraulic, Mil-H-6083
	Filter Element,
	Filter Element,
	Wipes, Lint-free
	Jars, Sample, Lint-free
	Cylinder, Graduated

B. Provided by contractor:

3 Sample Valves (each vendor)

C. Calibration hardware to support this TP.

2. Objective of Test: Demonstrate vendor's capability of meeting the design requirements called out on drawing No. 11784023.

3. Safety Precautions in Handling and Testing: TBD

4. Recommended Test Program

A. Each of the required valve samples supplied by a potential vendor shall be subjected to the following sequence of subtests to satisfy the Qualification Test requirement of paragraph 4.3 of QAP. Valves can be tested individually or as a batch(s) through subtest sequence.

B. Subtest 1 - Shock/Vibration Test

1) Test verifies compliance to Note 11.A on drawing 11784023.

2) Test procedure as depicted in Appendix B shall be followed to perform the test.

3) The test data form depicted in Appendix B shall be filled out for each execution of test procedure.

C. Subtest 2 - Climatic Test

1) Test verifies compliance to requirements 3.a, b, and c, 4.a, b, and c, 5.a and c, 6.a and c, and 7 of Table and note 11.B.6 on drawing 11784023.

2) Test procedure as depicted in Appendix C shall be followed to perform the test.

3) The test data form depicted in Appendix C shall be filled out for each execution of test procedure.

D. Subtest 3 - Endurance Test

1) Test verifies compliance to Note 11.B.7 on drawing 11784023.

2) Test procedure as depicted in Appendix D shall be followed to perform the test.

3) The test data form depicted in Appendix D shall be filled out for each execution of test procedure.

E. Subtest 4 - Functional Test

1) Test verifies compliance to requirements 1 through 12 of Table I and Note 14 on drawing 11784023.

2) Test procedure as depicted in Appendix A shall be followed to perform the test.

3) The test data form depicted in Appendix A shall be filled out for each execution of test procedure.

F. Subtest 5 - Weapon Elevation Rate/Hold Test

1) Test verifies compliance to Notes 11.B.1, 11.B.1.1, 11.B.2, 11.B.3, and 11.B.4 on drawing 11784023.

2) Test procedure as depicted in Appendix E shall be followed to perform the test.

3) The test data form depicted in Appendix E shall be filled out for each execution of test procedure.

5. References:

Valve Assembly, Lock	Drawing No.	11784023
Quality Assurance Provisions	QAP	11784023

6. Disposition

Sample valves shall be returned to submitter upon completion of test.

7. Type of Report and Security Classification

A. Letter report with copies of all test data forms generated as attachments.

B. Security Classification - Unclassified

8. Report Distribution

A. A copy of this test plan shall be included in the test report.

B. Statement C. Distribution authorized to U.S. Government Agencies and their contractors: Test and Evaluation, June 2, 1993. Other requests for this document shall be referred to OPM PALADIN, ATTN: SFAE-FAS-PAL, Picatinny Arsenal, NJ 07806-5000.

C. Copies to:

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APPENDIX A - FUNCTIONAL TEST

GENERAL PREPARATION

- Connect pressure and return lines (large and small lines) from test stand to reservoir.

- Fill reservoir with hydraulic fluid conforming to MIL-H-6083 so that fluid is seen in the level gage.

- Plug the power cord #1 into a 120 volt AC grounded wall outlet. The outlet should be capable of supplying 15 amps.

- Plug the power cord #2 into a 220 volt three phase AC grounded wall outlet. The outlet should be capable of supplying 30 amps.

- Turn switches M1, M3, V1, V2, and V3 to OFF position.

- Verify STOP switch is in ON position (out/released).

- Set cyclic controller switch to "By Passed".

- Press START button to energize stand.

- Make sure the O-rings at the A and B ports of the lock valve are properly installed. Mount the lock valve assembly to the hydraulic manifold so that the port identification markings are up-side-down.

Performance Requirement Number 1

1. Install plugs in ports Ml, M2, Pl and P2.

2. Connect the line from the hand pump to the High Pressure Y Adapter. Connect Y Adapter to Port A and Port B.

3. Close valve at the base of the hand pump by rotating fully clockwise until seated. The hand pump extension handle is notched for this purpose.

4. Operate hand pump until a pressure of 8,000 to 10,000 PSI is achieved.

5. After standing for 2 minutes at 8,000 to 10,000 PSI, check valve for external leakage. Record any leakage observed. No external leakage is permitted.

6. Relieve pressure by rotating valve at the base of the hand pump counter-clockwise.

7. Performance Requirement Number 1 is complete.

Performance Requirement Number 2

1. Remove Y-Adapter from A and B ports. (Quick disconnects should already be installed in M and P ports from Performance Requirement Number 1.)

2. Connect line l to Ml port. Connect line 2 to M2 port.

3. Place switches Sl and V3 in the ON position. (V2 OFF)

4. Rotate the knob at the base of the 200 PSI pressure gage fully counter-clockwise. Also rotate the knob on Throttle Valve 1 fully counter-clockwise.

5. Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) to indicate 75 +5 PSI on the 200 PSI pressure gage. Allow the system to run for 2 to 3 minutes to purge the air from the system.

6. Connect line l to Pl port. Connect line 2 to P2 port.

7. Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) to indicate 75 +5 PSI on the 200 PSI pressure gage. Allow the system to run for 2 to 3 minutes to purge the air from the system.

8. Turn the pump off and remove line 2. Attach the loose drain line to port M2 placing the open end in a graduated cylinder. First configuration in table below.

9. Run the pump for a predetermined period of time. (Suggest 10 minutes.

10. At the end of the predetermined time, turn the pump off and measure the volume of fluid collected. Divide the volume by the time and record the flow rate. Flow in excess of 6 cc per minute or less then 1 cc per minute will not be permitted. No leakage shall be evidenced at either port A or B.

11. Repeat steps 2 through 8 with line connections and switches according to the following table:

Pressure Line	Drain Line	Switches ON	Switches OFF
1 on M1	M2	V1	V2 & V3
1 on P1	P2	V1	V2 & V3
2 on M2	M1	V1 & V3	V2
2 on P2	P1	V1 & V3	V2

10. Performance Requirement Number 2 is complete. Turn switch M3 to OFF position to stop primary pump.

Performance Requirement Number 3

1. Install quick disconnects in all valve ports.

2. Connect lines l, 2, A, and B to their respective ports P1, P2, A, and B. No lines are to be connected to Ml, and M2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switch V1 ON position and switches V2 and V3 in the OFF position.

6.* Turn the primary pump on by setting switch M3 ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Turn Throttle Valve 1 clockwise until full flow through the lock valve is achieved. Do not exceed 370 PSI. Record maximum flow. Close valve to 600 PSI gage by turning clockwise fully.

8. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

9. Turn Throttle Valve 1 counter-clockwise until flow ceases.

10. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

11. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

12. Performance Requirement Number 3 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 4

1. Install quick disconnects in all valve ports.

2. Connect lines 1, 2, A, and B to their respective ports P1, P2, A, and B. No lines are to be connected to Ml and M2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switches V1, V2, and V3 in the ON position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Turn Throttle Valve 1 clockwise until full flow through the lock valve is achieved. Do not exceed 370 PSI. Record maximum flow. Close valve to 600 PSI gage by turning clockwise fully.

8. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

9. Turn Throttle Valve 1 counter-clockwise until flow ceases.

10. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

11. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

12. Performance Requirement Number 4 is complete.

* If additional pressure is desired on the lock valve/ Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 5

1. Install quick disconnects in all valve ports.

2. Connect lines l, 2, A, and B to their respective ports M1, M2, A, and B. No lines are to be connected to Pl, and P2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switch V1 in ON position and switches V2 and V3 in the OFF position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Turn Throttle Valve 1 clockwise until full flow through the lock valve is achieved. Do not exceed 370 PSI. Record maximum flow. Close valve to 600 PSI gage by turning clockwise fully.

8. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

9. Turn Throttle Valve 1 counter-clockwise until flow ceases.

10. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

11. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

12. Performance Requirement Number 5 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 6

1. Install quick disconnects in all valve ports.

2. Connect lines 1, 2, A, and B to their respective ports M1, M2, A, and B. No lines are to be connected to Pl, and P2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switches V1, V2, and V3 in the ON position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Turn Throttle Valve 1 clockwise until full flow through the lock valve is achieved. Do not exceed 370 PSI. Record maximum flow. Close valve to 600 PSI gage by turning clockwise fully.

8. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

9. Turn Throttle Valve 1 counter-clockwise until flow ceases.

10. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

11. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

12. Performance Requirement Number 6 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 7

1 . Remove all lines from ports Ml, M2, Pl and P2. Connect line A to port A and line B to port B.

2. Orient valve so ports M1, M2, P1, and P2 are facing down.

3 . Install appropriate adapters in ports Ml, M2, Pl and P2 .
(Fill with fluid as necessary.)

4. Adjust throttle valves to full counter clockwise position.

5. Rotate knob at the base of the 200 PSI gage full clockwise.

6. Start primary pump by setting switch M3 to ON. Place switch V2 in the ON position to test the A port.

7. Adjust throttle valve TV1 to obtain pressure of 200+/-10 PSI. Maintain for a minimum of four minutes.

8. Turn off pump by setting switch M3 to OFF and record the number of drops from Ml, M2, Pl, and P2 ports. Leakage to be three drops or less.

9. Repeat steps 6 through 8 with switch V2 in the OFF position to test the B port.

10. Performance Requirement Number 7 is complete..

Performance Requirement Number 8

1. Remove adapters from ports M1, M2, P1, and P2 and install quick disconnects.

2. Connect Line A to port A and Line B to port B.

3. Connect line 1 to port P1.

4. Connect line E to any M or P line in bundle and bundle line to port P2.

5. Set switch V1 to ON position and switches V2 and V3 to OFF position.

6. Adjust throttle valves to full counter-clockwise position.

7. Rotate knob at base of 200 PSI gage fully clockwise.

8. Turn primary and secondary pump on by setting switch M3 and M1 to ON.

9. Adjust Throttle Valve 3 (TV3) to indicate 200 PSI on the 600 PSI pressure gage G2 and adjust Throttle Valve 1 (TV1) to indicate 200 PSI on the 600 PSI pressure gage G1. Alternating between the two during pressure increase.

10. Turn Throttle Valve 1 clockwise until flow is evident. Do not exceed 370 PSI. Record pressure when flow becomes evident. Flow evident at pressures below 325 PSI will not be permitted.

11. Rotate Throttle Valve 1 counter-clockwise until 200 PSI is indicated on the 600 PSI pressure gage G1.

12. Turn off pumps by setting switch M3 and M1 to OFF.

13. Disconnect lines 1 and bundle line connected to line E from ports P1 and P2.

14. Connect bundle line connected to line E to port P1 and line 1 to Port P2.

15. Repeat steps 8 through 13.

16. Performance Requirement Number 8 is complete.

Performance Requirement Number 9

1. Connect line G to bundle line B and line F to bundle line A.

2. Connect bundle line B to port B and bundle line A to port A.

3. Connect line 1 to port P1 and line 2 to port P2.

4. Set switch V1 to On and switches V2 and V3 to OFF position.

5. Adjust Throttle Valves to full counter-clockwise position.

6. Rotate knob at base of 200 PSI gage fully counter-clockwise position.

7. Turn primary and secondary pumps on by setting switches M3 and M1 to ON.

8. Adjust Throttle Valve 3 (TV3) to indicate 500 PSI on the 600 PSI pressure gage G2.

9. Adjust Throttle Valve 1 (TV1) to indicate 50 PSI on the 200 PSI pressure gage.

10. Turn Throttle Valve 1 clockwise until flow is evident. Do not exceed 170 PSI. Record pressure when flow becomes evident. Flow evident at pressures below 125 PSI will not be permitted.

11. Rotate Throttle Valve 1 counter-clockwise until 50 PSI is indicated on the 200 PSI pressure gage.

12. Turn off pumps by setting switches M3 and M1 to OFF.

13. Disconnect line 1 from port P1.

14. Disconnect line 2 from port P2.

15. Connect line 1 to port P2 and line 2 to Port P1.

16. Repeat steps 7 through 12.

17. Performance Requirement Number 9 is complete.

Performance Requirement Number 10

1. Remove adapters from ports M1, M2, P1, and P2 and install quick disconnects.

2. Connect line A to port A and line B to port B.

3. Connect line 1 to port M1.

4. Connect line E to any M or P line in bundle and bundle line to port M2.

5. Set switch to ON position and switches V2 and V3 to OFF position.

6. Adjust Throttle Valves to full counter-clockwise position.

7. Rotate knob at base of 200 PSI gage fully clockwise.

8. Turn primary and secondary pump on by setting switches M3 and M1 to ON.

9. Adjust Throttle Valve 3 (TV3) to indicate 200 PSI on the 600 PSI pressure gage G2 and adjust Throttle Valve 1 (TV1) to indicate 200 PSI on the 600 PSI pressure gage G1. Alternating between the two during pressure increase.

10. Turn Throttle Valve 1 clockwise until flow is evident. Do not exceed 370 PSI. Record pressure when flow becomes evident. Flow evident at pressures below 325 PSI will not be permitted.

11. Rotate Throttle Valve 1 counter-clockwise until 200 PSI is indicated on the 600 PSI pressure gage G1.

12. Turn off pumps by setting switches M3 and M1 to OFF.

13. Disconnect lines 1 and bundle line connected to line E from ports M1 and M2.

14. Connect bundle line connected to line E to port M2 and line 1 to Port M1.

15. Repeat steps 8 through 13.

16. Performance Requirement Number 10 is complete.

Performance Requirement Number 11

1. Connect line G to bundle line B and line F to bundle line A.

2. Connect bundle line B to port B and bundle line A to port A.

3. Connect line 1 to port M1 and line 2 to port P2.

4. Set switch V1 to On and switches V2 and V3 to OFF position.

5. Adjust Throttle Valves to full counter-clockwise position.

6. Rotate knob at base of 200 PSI gage fully counter-clockwise position.

7. Turn primary and secondary pump on by setting switches M3 and M1 to ON.

8. Adjust Throttle Valve 3 (TV3) to indicate 500 PSI on the 600 PSI pressure gage G2.

9. Adjust Throttle Valve 1 (TV1) to indicate 50 PSI on the 200 PSI pressure gage.

10. Turn Throttle Valve 1 clockwise until flow is evident. Do not exceed 170 PSI. Record pressure when flow becomes evident. Flow evident at pressures below 125 PSI will not be permitted.

11. Rotate Throttle Valve 1 counter-clockwise until 50 PSI is indicated on the 200 PSI pressure gage.

12. Turn off pumps by setting switches M3 and M1 to OFF.

13. Disconnect line 1 from port M1.

14. Disconnect line 2 from port M2.

15. Connect line 1 to port M2 and line 2 to Port M1.

16. Repeat steps 7 through 12.

17. Performance Requirement Number 11 is complete.

Performance Requirement Number 12

1. Connect Line A to Y adapter and Y adapter to Ports A and B.

2. Install male quick disconnects on ports M1, M2, P1, and P2 if not already installed.

3. Install quick disconnects with tubes to ports P1 and M1.

4. Place graduated receptacle under the two tubes to collect fluid.

5. Rotate the knob at the base of the 200 PSI pressure gage and the 600 PSI pressure gage G1 fully counter-clockwise. Also, rotate the knob on Throttle Valve 1 fully counter-clockwise.

6. Place switches V1 and V3 in the ON position and switch V2 to Off position.

7. Turn primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) to indicate 2000 PSI on the 3000 PSI pressure gage or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved. Run pump for a predetermined time.

8. At the end of the predetermined time, turn the pump off by setting switch M3 to OFF and measure the volume of fluid collected. Divide the volume collected by the time and multiply by the number of drops per graduation. Record rate. Flow less than 4 drops per minute will not be permitted.

9. Transfer quick disconnects with tubes from ports M1 and P1 to M2 and P2.

10. Repeat steps 4 through 8.

11. Performance Requirement Number 12 is complete.

Test Documentation Sheet
for Lock Valve PN 11784023

FUNCTIONAL TEST

Contract:_____ Test Date:_____

Manufacturer:_____

Sample #:_____ Test Time:_____

Test 1:

PORT A:	Leakage	or	No Leakage
PORT B:	Leakage	or	No Leakage

Test 2:

Port	Flow(cc)	Duration(sec.)	Flow Rate(cc/sec)
M1	_____	_____	_____
P1	_____	_____	_____
M2	_____	_____	_____
P2	_____	_____	_____

Test 3: P1 to B

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 4: P2 to A

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 5: M1 to B

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 6: M2 to A

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 7:

At 200 psi

Port A _____ drops / 4 minutes

Port B _____ drops / 4 minutes

Test 8:

a. Port P1 On Pressure (psi)_____

b. Port P2 On Pressure (psi)_____

Test 9:

a. Port P1 On Pressure (psi)_____

b. Port P2 On Pressure (psi)_____

Test 10:

a. Port M1 On Pressure (psi)_____

b. Port M2 On Pressure (psi)_____

Test 11:

a. Port M1 On Pressure (psi)_____

b. Port M2 On Pressure (psi)_____

Test 12:

Total Leakage Volume (cc):_____

Duration: _____

Leakage Rate (cc/sec.):_____

APPENDIX B - SHOCK/VIBRATION TEST

1. Shock and vibration testing shall be conducted in accordance with Mil-Std-810E which is entitled "Environmental Test Methods and Engineering Guidelines".

2. The shock shall be conducted in accordance with method 516.4, procedure 1. The vibration shall be conducted in accordance with method 514.4, category 8.

3. All the requirements of Mil-Std-810E apply with the exception that the tolerance on time in paragraph 5.1.1 be changed from +/- 1% to +/- 10%.

4. The following tables are provided for easy reference for the magnitude, frequency, time duration, and tolerances.

Shock

Each valve hall be subjected to 3 half-sine wave impulses for each combination in table 1.

Axis	Magnitude (g's)	Duration (millisec.)
X	30 +/- 3	11 +/- 1.1
Y	30 +/- 3	11 +/- 1.1
Z	30 +/- 3	11 +/- 1.1
X	55 +/- 5.5	2.5 +/- 0.25
Y	55 +/- 5.5	2.5 +/- 0.25
Z	55 +/- 5.5	2.5 +/- 0.25
X	70 +/- 7	0.5 +/- 0.05
Y	70 +/- 7	0.5 +/- 0.05
Z	70 +/- 7	0.5 +/- 0.05

TABLE 1

Vibration

Each valve hall be subjected to each combination in table 2.

Axis	Frequency (Hz)	Frequency Tolerance	Magnitude	Magnitude Tolerance
X	5 - 25	+/- 2%	+/- 1.5 G	+/- 0.15 G
Y	5 - 25	+/- 2%	+/- 1.5 G	+/- 0.15 G
Z	5 - 25	+/- 2%	+/- 1.5 G	+/- 0.15 G
X	25 - 50	+/- 2%	0.030 IN	+/- 0.003 IN
Y	25 - 50	+/- 2%	0.030 IN.	+/- 0.003 IN
Z	25 - 50	+/- 2%	0.030 IN.	+/- 0.003 IN
X	50 - 500	+/- 2%	+/- 5.0 G	+/- 0.5 G
Y	50 - 500	+/- 2%	+/- 5.0 G	+/- 0.5 G
Z	50 - 500	+/- 2%	+/- 5.0 G	+/- 0.5 G

TABLE 2

Shock and Vibration
Test Document Sheet

Manufacturer:_____
Sample #:_____ Test date:_____

Shock

Axis	Magnitude	Duration

Vibration

Axis	Frequency	Magnitude

APPENDIX C - CLIMATIC TEST

GENERAL PREPARATION

- Connect pressure and return lines (large and small lines) from test stand to reservoir.

- Fill reservoir with hydraulic fluid conforming to MIL-H-6083 so that fluid is seen in the circular "bulls eye" level gage.

- Plug the power cord #1 into a 120 volt AC grounded wall outlet. The outlet should be capable of supplying 15 amps.

- Plug the power cord #2 into a 220 volt three phase AC grounded outlet. The outlet should be capable of supplying 30 amps.

- Make sure the O-rings at the A and B ports of the lock valve are properly installed. Mount the lock valve assembly to the hydraulic manifold so that the port identification markings are up-side-down.

- Plug the power cord of the Fluid Chiller into a 220 volt single phase AC grounded wall outlet. The outlet should be capable of supplying 30 amps.

- Remove valve stand from test stand and connect Valve Stand Remote Bundle. Place Valve Stand in a suitable climatic cell.

- Remove reservoir from cart and install into climatic cell after installing Reservoir Remote Bundle to reservoir and test stand.

- Condition reservoir, valve stand, and valves to be tested to -50 deg. Fahrenheit until temperature uniform throughout items.

- Remove Reservoir from chamber and install into insulated enclosure.

- Install Fluid Chiller Probe into reservoir.

- Install insulation on lines and reservoir.
- Turn switches M1, M3, V1, V2, and V3 to OFF position.

- Ensure STOP switch is in ON position (out/released).

- Set cyclic controller switch to "By Passed".

- Press START button to energize stand.

- Run Fluid Chiller until fluid temperature stabilizes at -50 degrees Fahrenheit. Circulate fluid and adjust Chiller so that the fluid temperature as it enters the Valve Stand Remote Bundle is at -50 degrees Fahrenheit.

Performance Requirement Number 3

1. Install quick disconnects in all valve ports.

2. Connect lines l, 2, A, and B to their respective ports P1, P2, A, and B. No lines are to be connected to Ml, and M2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switch V1 ON position and switches V2 and V3 in the OFF position.

6.* Turn the primary pump on by setting switch M3 ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 3 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 4

1. Install quick disconnects in all valve ports.

2. Connect lines 1, 2, A, and B to their respective ports P1, P2, A, and B. No lines are to be connected to Ml and M2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switches V1, V2, and V3 in the ON position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 4 is complete.

* If additional pressure is desired on the lock valve/ Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 5

1. Install quick disconnects in all valve ports.

2. Connect lines l, 2, A, and B to their respective ports M1, M2, A, and B. No lines are to be connected to Pl, and P2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switch V1 in ON position and switches V2 and V3 in the OFF position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 5 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 6

1. Install quick disconnects in all valve ports.

2. Connect lines 1, 2, A, and B to their respective ports M1, M2, A, and B. No lines are to be connected to Pl, and P2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switches V1, V2, and V3 in the ON position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 6 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Test Documentation Sheet
for Lock Valve PN 11784023

CLIMATIC TEST

COLD PHASE

Contract:_____ Test Date:_____

Manufacturer:_____

Sample #:_____ Test Time:_____

Chamber Temperature (At Start of Test):_____

Oil Temperature (At Start of Test):_____

Test 3: P1 to B

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 4: P2 to A

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 5: M1 to B

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 6: M2 to A

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Chamber Temperature (At End of Test):_____ Test End Date:_____

Oil Temperature (At End of Test):_____ Test End Time:_____

GENERAL PREPARATION

- Connect pressure and return lines (large and small lines) from test stand to reservoir.

- Fill reservoir with hydraulic fluid conforming to MIL-H-6083 so that fluid is seen in the circular "bulls eye" level gage.

- Plug the power cord into a 120 volt AC grounded wall outlet. The outlet should be capable of supplying 15 amps.

- Make sure the O-rings at the A and B ports of the lock valve are properly installed. Mount the lock valve assembly to the hydraulic manifold so that the port identification markings are up-side-down.

- Mount Valve Stand onto the test stand.

- Wire each Fluid Heater into a 220 volt single phase AC grounded Breaker box. The Breaker box should be capable of supplying 12 amps.

- Turn switches M1, M3, V1, V2, and V3 to OFF position.

- Ensure STOP switch is in on position (out/released).

- Set cyclic controller switch to "By Passed".

- Press START button to energize stand.

- Install insulation on lines and reservoir.

- Run Fluid Heater until fluid temperature stabilizes at 250 degrees Fahrenheit while circulating the fluid. Adjust Heater so that the fluid temperature as it enters the Valve Stand is at 250 degrees Fahrenheit.

Performance Requirement Number 3

1. Install quick disconnects in all valve ports.

2. Connect lines l, 2, A, and B to their respective ports P1, P2, A, and B. No lines are to be connected to Ml, and M2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switch V1 ON position and switches V2 and V3 in the OFF position.

6.* Turn the primary pump on by setting switch M3 ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 3 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 4

1. Install quick disconnects in all valve ports.

2. Connect lines 1, 2, A, and B to their respective ports P1, P2, A, and B. No lines are to be connected to Ml and M2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switches V1, V2, and V3 in the ON position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 4 is complete.

* If additional pressure is desired on the lock valve/ Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 5

1. Install quick disconnects in all valve ports.

2. Connect lines l, 2, A, and B to their respective ports M1, M2, A, and B. No lines are to be connected to Pl, and P2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switch V1 in ON position and switches V2 and V3 in the OFF position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 5 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Performance Requirement Number 6

1. Install quick disconnects in all valve ports.

2. Connect lines 1, 2, A, and B to their respective ports M1, M2, A, and B. No lines are to be connected to Pl, and P2.

3. Rotate knobs on both Throttle Valves fully counter-clockwise.

4. Rotate knob at the base of the 200 PSI gage fully counterclockwise.

5. Place switches V1, V2, and V3 in the ON position.

6.* Turn the primary pump on by setting switch M3 to ON and adjust Throttle Valve 1 (TV1) clockwise until flow is evident. (Note: Do not exceed 200 PSI. If flow is not evident by 200 PSI, rotate knob at the base of the 200 PSI gage fully clockwise and continue testing using the 600 PSI gage.) Record the pressure at which flow becomes evident.

7. Continue turning Throttle Valve 1 until the pressure indicated on the 3000 PSI pressure gage reads between 925 PSI and 950 PSI or has seated, if pressure not within range turn Throttle Valve 2 clockwise until required pressure achieved.

8. Turn Throttle Valve 1 counter-clockwise until flow ceases.

9. Record the pressure at which flow ceased. (Note: If the pressure is less then 200 PSI, turn the knob at the base of the 200 PSI gage fully counter-clockwise and read the pressure from the 200 PSI gage.) Pressure when the flow ceases shall be within 50 PSI of the pressure required to initiate flow.

10. Turn off pump by setting switch M3 to OFF and place all switches in the OFF position.

11. Performance Requirement Number 6 is complete.

* If additional pressure is desired on the lock valve, Throttle Valve 2 (TV2) can be rotated clockwise.

Test Documentation Sheet
for Lock Valve PN 11784023

CLIMATIC TEST

HOT PHASE

Contract:_____ Test Date:_____

Manufacturer:_____

Sample #:_____

Chamber Temperature (At Start of Test):_____

Oil Temperature (At Start of Test):_____

Test 3: P1 to B

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 4: P2 to A

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 5: M1 to B

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 6: M2 to A

a. On Pressure (psi) _____

b. Flow (gpm)_____ at psi_____

c. Off Pressure (psi)_____

d. Off Pressure (psi)_____

Test 7:

At 200 psi

Port A _____ drops / 4 minutes

Port B _____ drops / 4 minutes

Chamber Temperature (At End of Test):_____ Test End Date:_____

Oil Temperature (At End of Test):_____ Test End Time:_____

APPENDIX D - ENDURANCE TEST

GENERAL PREPARATION

- Connect pressure and return lines (large and small lines) from test stand to reservoir.

- Fill reservoir with hydraulic fluid conforming to MIL-H-6083 so that fluid is seen in the circular "bulls eye" level gage.

- Plug the power cord #1 into a 120 volt AC grounded wall outlet. The outlet should be capable of supplying 15 amps.

- Plug the power cord #2 into a 220 volt three phase AC grounded outlet. The outlet should be capable of supplying 30 amps.

- Turn switches M1 and M3 OFF and V1, V2, and V3 to ON.

- Insure STOP switch is in ON position (out/released).

- Set cyclic controller switch to NORMAL.

- Press START button to energize the stand.

- Make sure the O-rings at the A and B ports of the lock valve are properly installed. Mount the lock valve assembly to the hydraulic manifold so that the port identification markings are up-side-down.

Test Procedure

1) Rotate knobs at base of 200 and 600 PSI gages fully clockwise.

2) Connect Line 1 to port P1, line 2 to port P2, line A to port A, and line B to port B.

3) Turn on primary pump by setting switch M3 to ON and adjust throttle valve VT1 to obtain pressure of 1250 PSI. Adjust throttle valve VT2 if required to obtain required pressure.

4) Set cyclic controller power switch to ON.

5) Press START on controller to start test. After controller stops, record results and reset controller if counter reads 18000 or HP1 or HP2 status lights are on. If LP status light is on, do not reset counter and correct servo valve failure and continue test..

6) Turn off pump by setting switch M3 to OFF.

7) Connect line 1 to port M1 and line 2 to port M2 and repeat steps 3 to 5.

8) Test completed.

NOTE: HP1 and HP2 indicator lights ON indicate Lock Valve failure to shift spool. LP indicator light ON indicates stand sevo valve failure.

ENDURANCE TEST DATA SHEET

MANUFACTURER:_____

SN:_____

DATE TEST STARTED:_____

TIME TEST STARTED:_____

DATE TEST ENDED:_____

TIME TEST ENDED:_____

CYCLE COUNTER READING AT START:_____

CYCLE COUNTER READING AT END:_____

INDICATOR STATUS AT END OF TEST

INDICATOR	LIGHT ON?	
LP	Y	N
HP1	Y	N
HP2	Y	N

APPENDIX E - WEAPON ELEVATION RATE/HOLD TEST

GENERAL PREPARATION

1. An M109A6 will be used to test the lock valve's on-vehicle performance.

2. Prior to installing the valve, ensure that the gun is in travel lock and the hydraulic system is properly discharged (para. 18-1 a. from TM 9-2350-314-20-2-2).

3. Remove the presently installed lock valve, and replace it with the test lock valve (para. 10-8 b. and c. from TM 9-2350-314-34-2.). The removed lock valve should be properly plugged and placed into protective packaging to ensure the valve is not contaminated.

4. Prior to the initiation of testing, ensure that the equilibration/elevation system is properly charged (para 28-10 of TM 9-2350-314-20-2-2), bled, and equilibrated (para. 18-1 e. and f. of TM 9-2350-314-20-2-2).

5. The ability to retain a set elevation over a period of time shall be verified. Elevate the gun tube to 700 mils and verify using a gunner's quadrant. Record the time and elevation. Allow the vehicle to remain undisturbed for one hour. Then use the gunner's quadrant to determine the elevation. Record the time and elevation. Determine the differences between the times and elevations. For a minimum time difference of one hour there is a maximum allowable elevation difference of 1.5 mils. The fluid temperature must remain at 75 +/- 5 degrees F during the test.

6. The gun tube cycle time between 0 mils and max. elevation shall be verified. Turn the hydraulics on and set the gun tube elevation at 0 mil. Use the COS control handle to raise the gun tube to max. elevation at full speed. Measure and record the amount of time expended to complete this operation. Starting with the gun tube at max. elevation, use the COS handle to lower the gun tube to 0 mils at full speed. Measure and record the time expended to complete this operation. In both cases (elevation and depression) the expended time shall not exceed 11 seconds. The ambient temperature must be 70 +/- 15 degrees F and the fluid temperature must be 90 +/- 30 degrees F. Repeat this procedure twice.

7. The gun elevation rate in mils per sec shall be measured for varying degrees of gun control handle actuation. Bring the gun tube to the lower stop and with the hydraulics off, pull the COS control handle 7.5 degrees off the centered position. Turn the hydraulic on and allow the gun to elevate to the upper stop. Use the vehicle's elevation tachometer to determine the elevation rate while simultaneously using the DRU to determine the elevation. This data will be used to create plots of elevation velocity verses time for the ranges of 0-300 mils, 500-800 mils, and 1000-1300 mils. This shall be repeated with the control handle at 10, 15, 20, 25, and 30 degrees off neutral position. For each curve, there shall be no oscillation greater than +/- 5% about the curveÕs mean value. The velocity at 533 mils for each control handle position shall be used to create a second plot of velocity verses handle position. This curve shall have no inflection points.

8. The gun elevation rate in mils per sec shall be measured for a constant manual elevation hand pump rotation. Remove the manual elevation pump handle assembly (para. 10-14 a. TM 9-2350-314-34-2) and install a gear in its place. The gear should be mated with another gear that is mounted to an electric motor. The electric motor will be used to elevate the gun at a constant handle rotation. A plot of the elevation velocity verses time shall be created for motion between 400 and 700 mils. The curve shall fall within +/- 5% of the mean curve.

9. The elevation/depression rate shall be measured for the full range of gun elevations. Using the COS control handle, the gun shall be elevated from the lower gun stop to the upper gun stop while the elevation rate is recorded. This shall be repeated while going from max. elevation to max. depression. The minimum elevation/depression rate shall be no less than 130 mils/sec.

10. During conduct of the above test procedures, there is no allowable motion from the manual elevation hand crank during power elevation. (Motion would most likely occur when the gun is brought into either the upper or lower stop.)

11. This completes the on vehicle tests for the valve. The above procedure should now be duplicated for any additional valves. If there are no additional valves, then the howitzer should be returned to the original configuration.

On Vehicle Testing
Test Document Sheet

Manufacturer:_____ Sample #:_____
Test date:_____

Gun Droop

Start Time_____ Elevation_____
Finish Time_____ Elevation_____
Time Duration_____ Elevation Delta_____

Gun Cycle Time

Elevation time_____ Depression Time_____
Elevation time_____ Depression Time_____
Elevation time_____ Depression Time_____

Gun Velocity at 533 Mils

Off Center Position of Control Handle_____ Velocity_____
Off Center Position of Control Handle_____ Velocity_____
Off Center Position of Control Handle_____ Velocity_____
Off Center Position of Control Handle_____ Velocity_____
Off Center Position of Control Handle_____ Velocity_____
Off Center Position of Control Handle_____ Velocity_____

APPENDIX B

HYDRAULIC CONTAMINATION CONTROL

AMSTA-AR-FSA-W 2 Mar 95

MEMORANDUM FOR RECORD

SUBJECT: Hydraulic Contamination Control

1. The purpose of this memo is to provide guidance material to be followed during the hydraulic testing of M109 lock valves. Adherence to the following instructions will assure that the requisite cleanliness level 200 of MIL-STD-1246 is met.

2. Instructions for lock valve testing include:

- Gross cleaning as specified in MIL-STD-1246B will be employed.
- The test area will be maintained in a visually clean state.
- Only clean lint free rags will be used on the test stand and components.
- The lock valve protective packaging will not be opened until the valve is required for testing. The packaging will be cleaned before movement to the test stand to remove dust and dirt. This will apply to any other hydraulic components needed for the test stand.
- All open ports and fittings will be plugged or capped immediately when not in use. Plugs or caps will only be removed immediately prior to connecting that particular port or fitting.
- Hydraulic components will not remain unattended or unprotected.
- Any components removed from the test stand will be properly capped or plugged and stored in protective packaging.
- Compressed air will not at any time be permitted to clean hydraulic components.
- Dry sweep will not be used in the hydraulic areas.
- All hand tools and equipment used will be kept clean through the testing process.

3. Prior to testing, the test stand shall have new filters installed and will be flushed using a dummy lock valve. A hydraulic fluid sample will be taken and analyzed to ensure compliance with level 200 of MIL-STD-1246. Only certified clean sample bottles will be allowed.

4. All testing will be performed using the facilities located at Picatinny Arsenal. Picatinny does not have access to a hydraulic fluid particle counter to analyze fluid samples during the qualification testing. For this reason, it is deemed necessary to document that adherence to the above guidelines while performing the actual test sequence will produce acceptable oil contamination levels. A control set of Kemp locking valves will be run through the full set of tests and a fluid sample will be taken during each distinct phase. The samples will be analyzed and favorable results will be considered basis for qualifying the stand and the above guidelines.

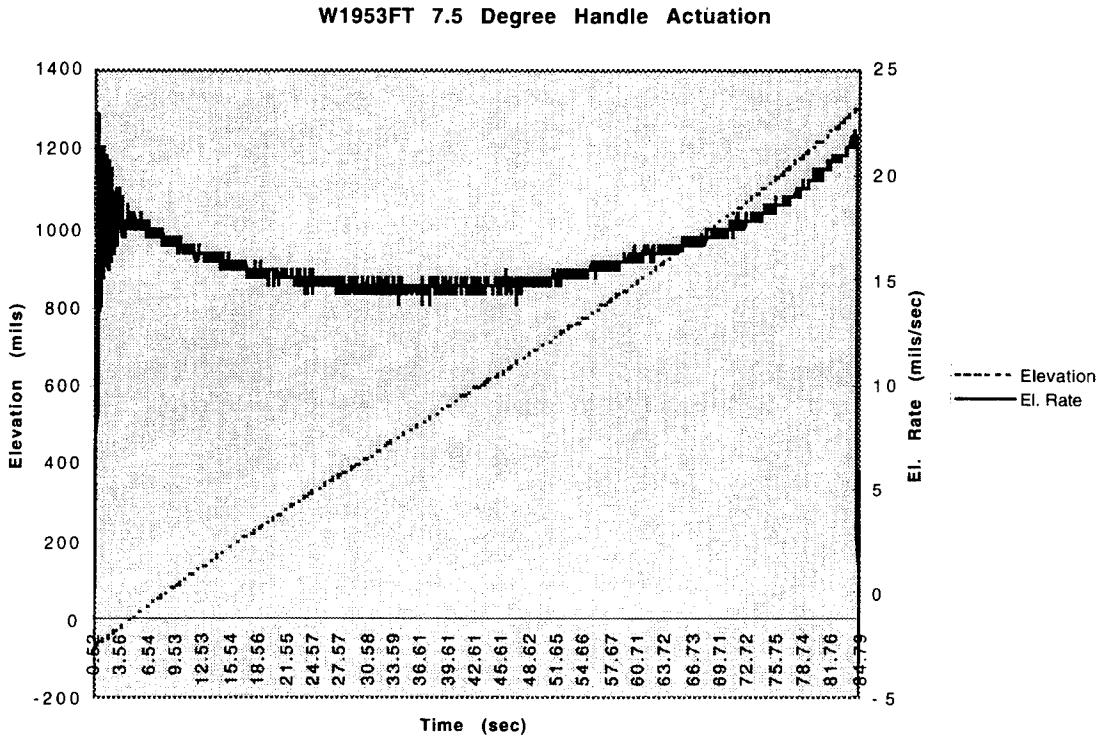
5. Oil samples will only be taken during the qualification testing if there is a valve failure. The sample will be taken as soon as possible after the failure, but under no circumstances will the hydraulic system be opened before a sample is taken.

6. POC for this matter is Paul Kida, x2733.

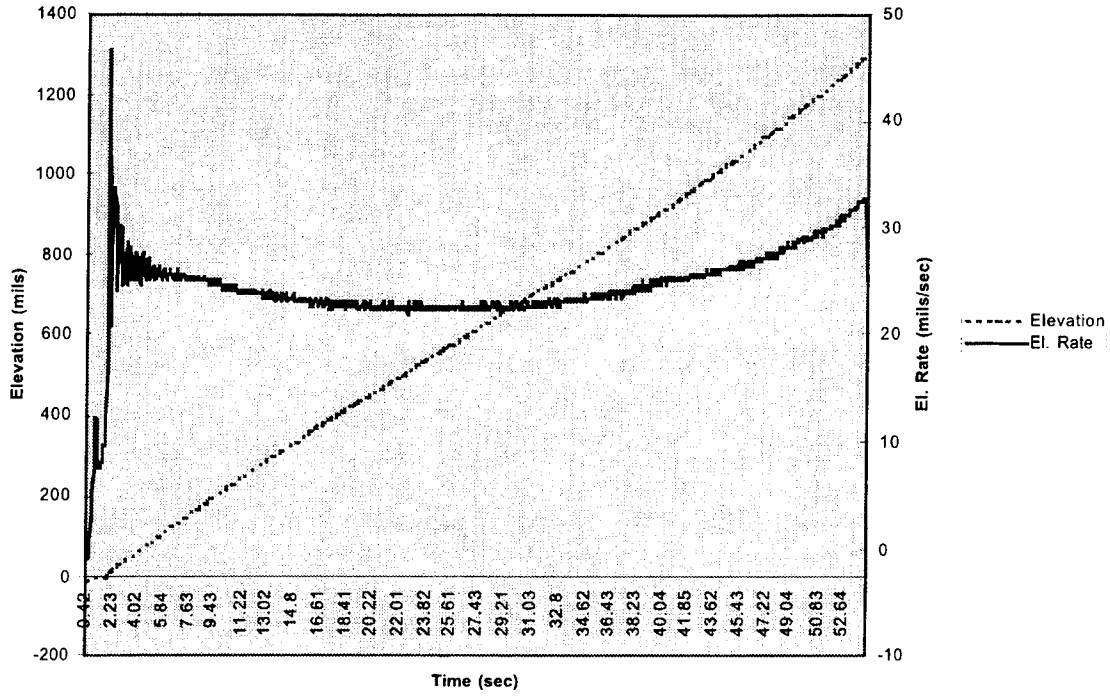
Paul R. Kida
GS-12 Mechanical Engineer

APPENDIX C

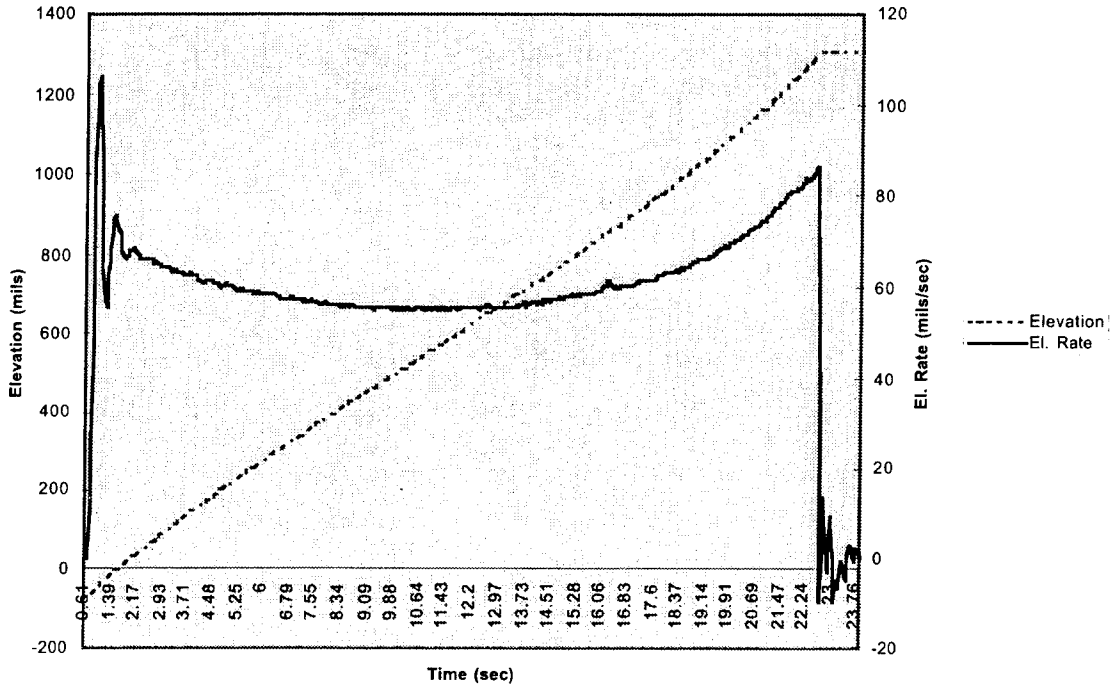
ON-WEAPON TEST DATA PLOTS


W1953FT 7.5 Degree Handle Actuation
1400
1200
1000
800
600
400
200
0
-200
Elevation (mils)
25
20
15
10
5
0
- 5
El. Rate (mils/sec)
3.56
6.54
9.53
12.53
15.54
18.56
21.55
24.57
27.57
30.58
33.59
36.61
39.61
42.61
45.61
48.62
51.65
54.66
57.67
60.71
63.72
66.73
69.71
72.72
75.75
78.74
81.76
Time (sec)
Elevation
El. Rate

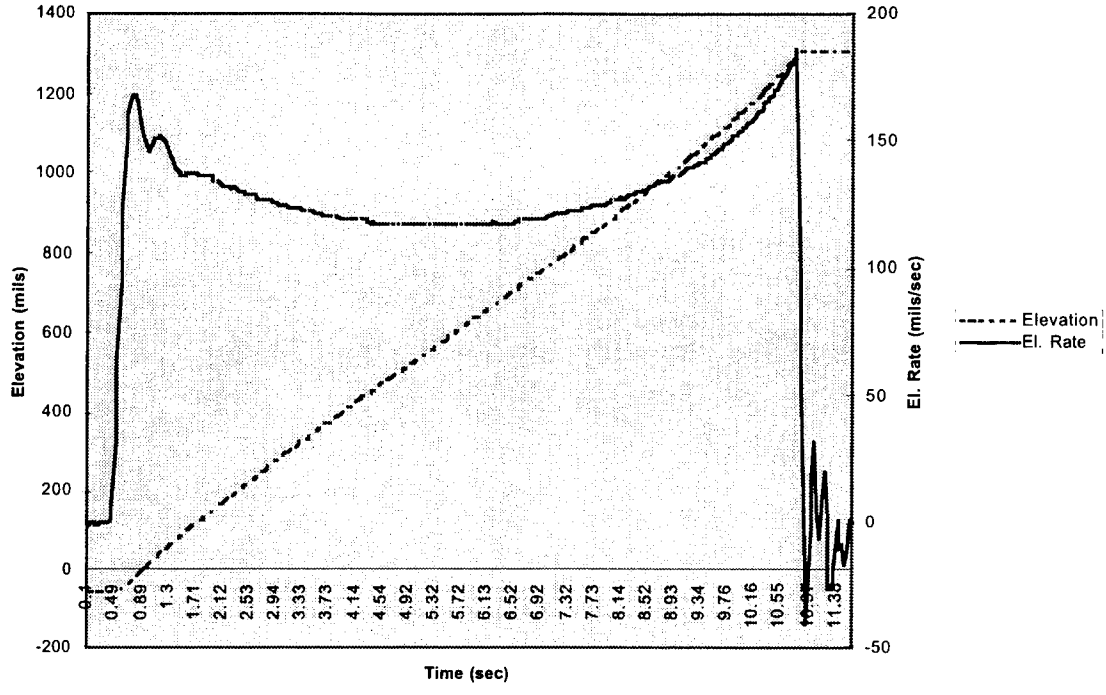
W1953FT 10 Degree Handle Actuation



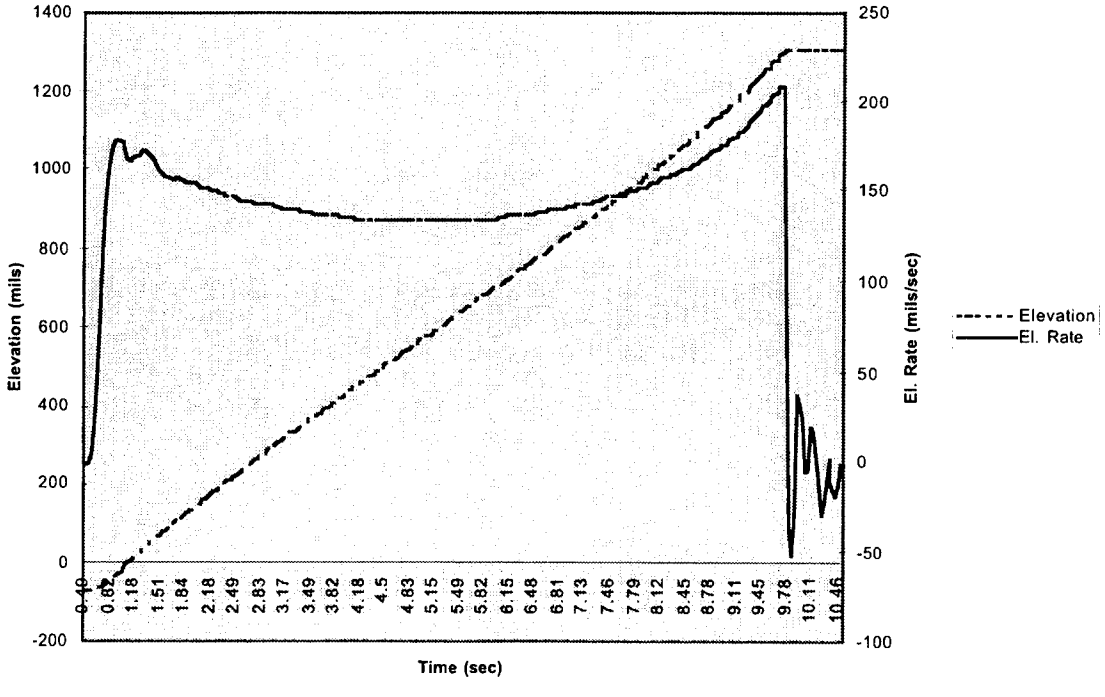
W1953FT 15 Degree Handle Actuation

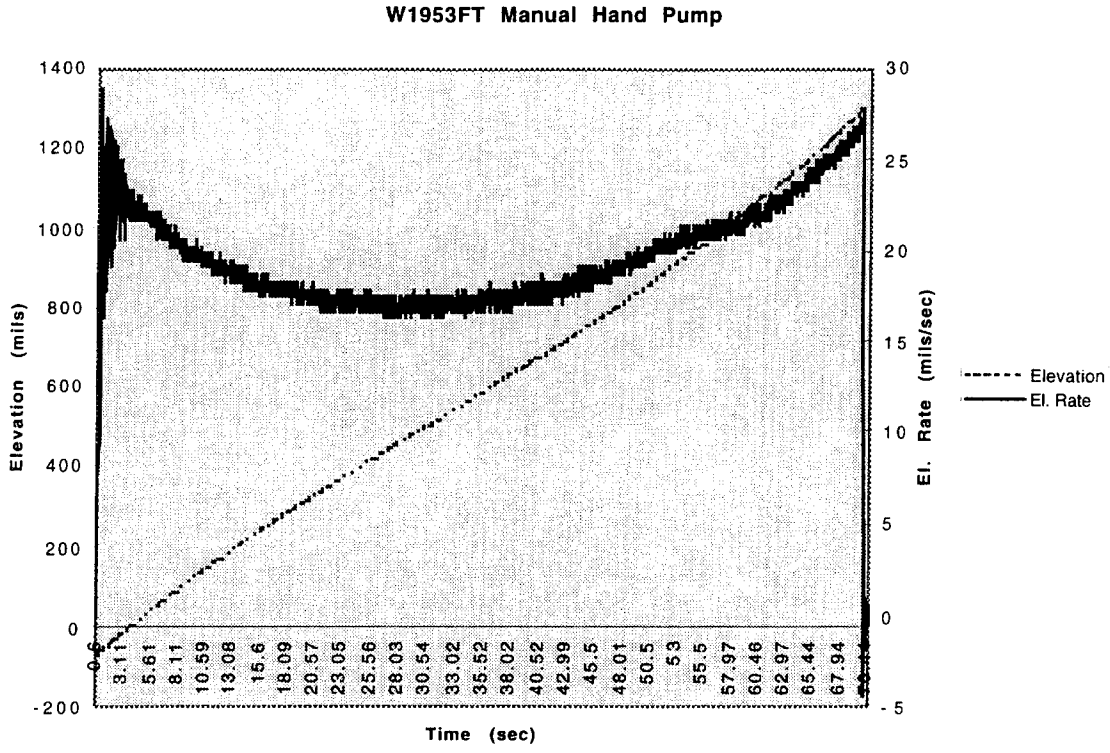


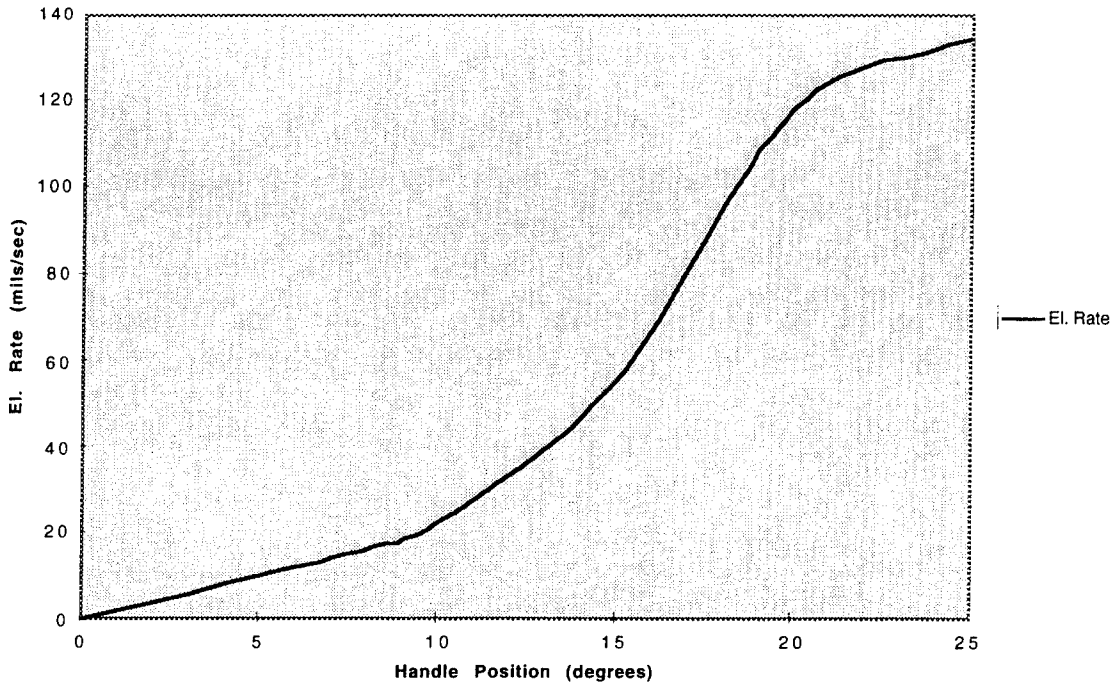
W1953FT 20 Degree Handle Actuation



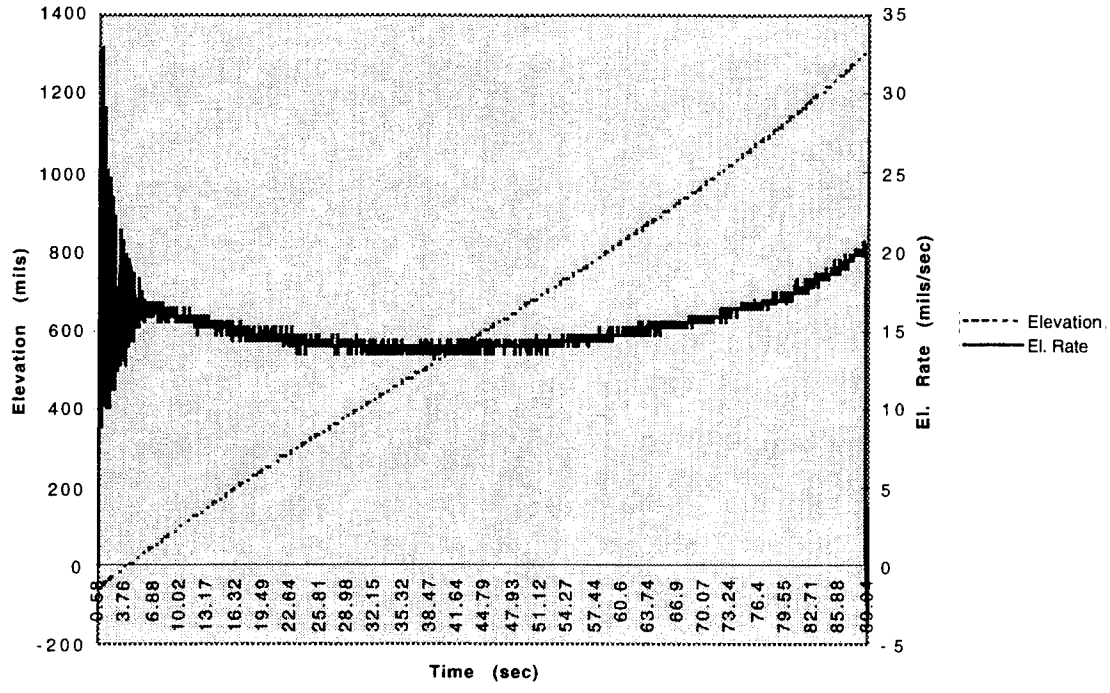
W1953FT 25 Degree Handle Actuation



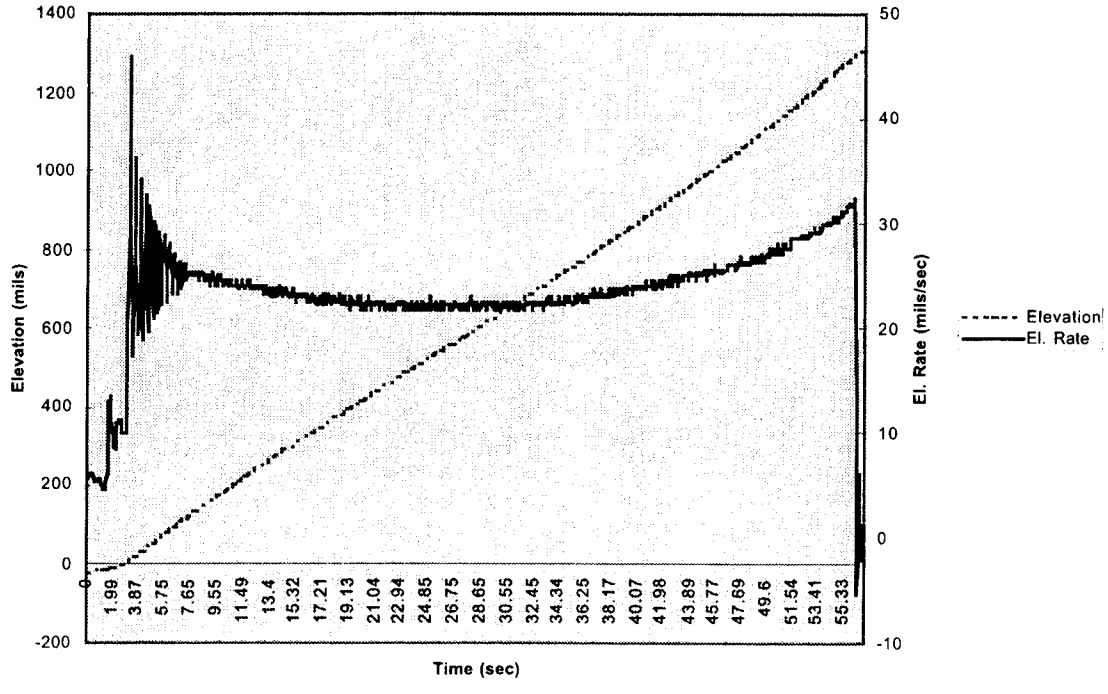

W1953FT Manual Hand Pump
Elevation (mils)
El. Rate (mils/sec)
Time (sec)
Elevation
El. Rate


W1953FT El. Rate vs. Handle Position (533 mils)
El. Rate (mils/sec)
Handle Position (degrees)
El. Rate

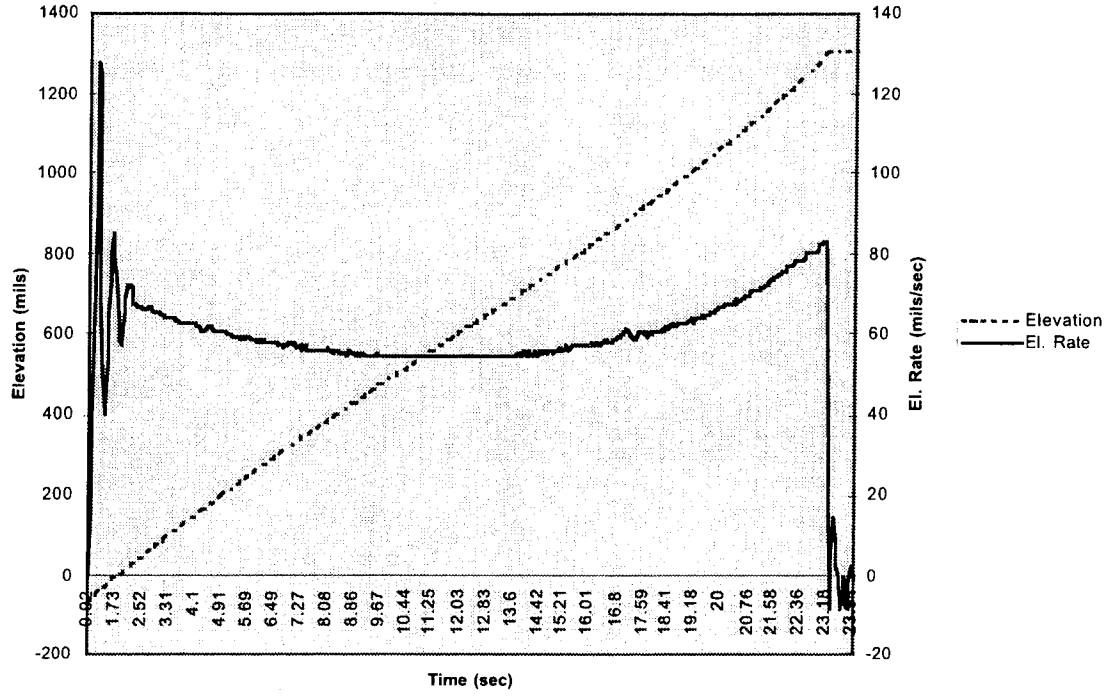
W1955FT 7.5 Degree Handle Actuation



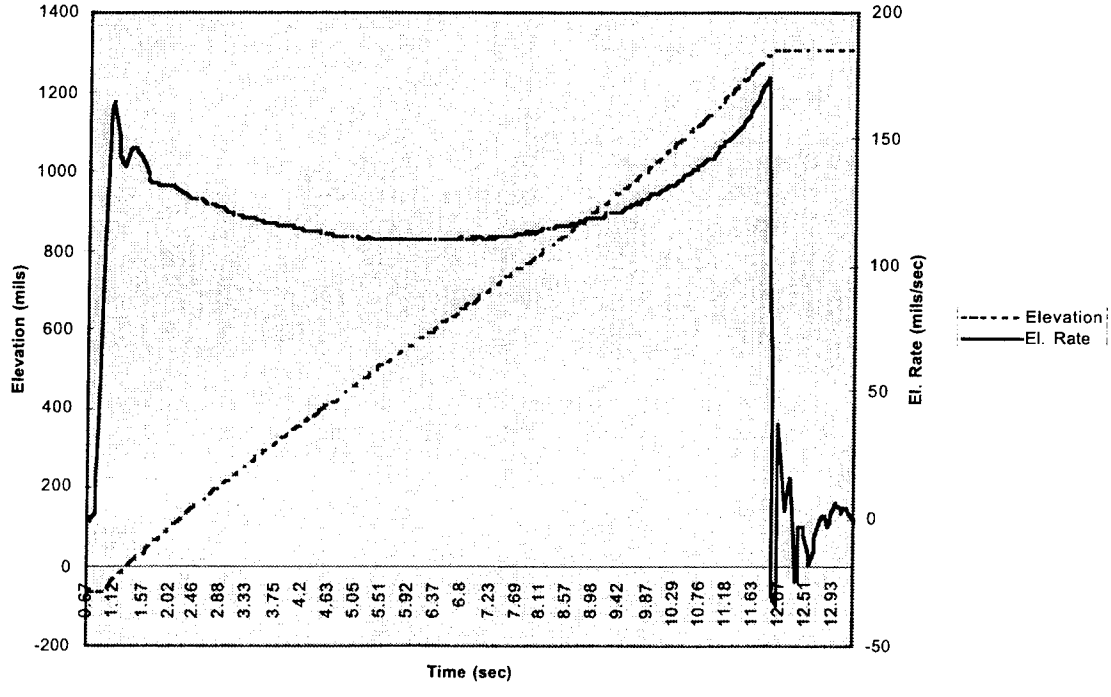
W1955FT 10 Degree Handle Actuation



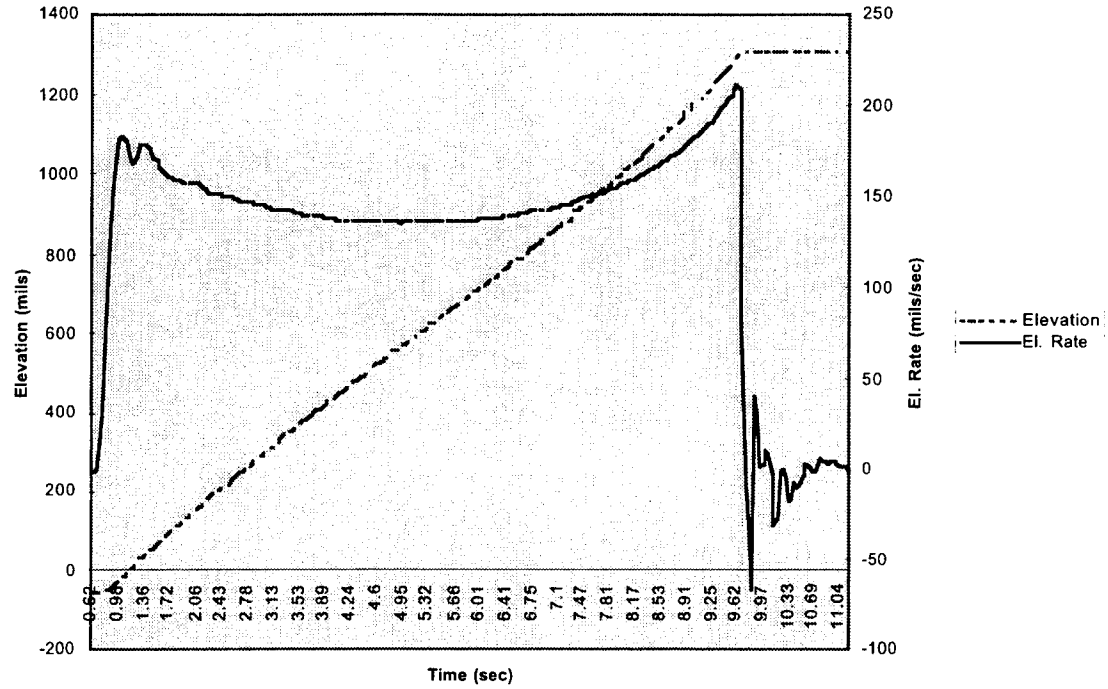
W1955FT 15 Degree Handle Actuation



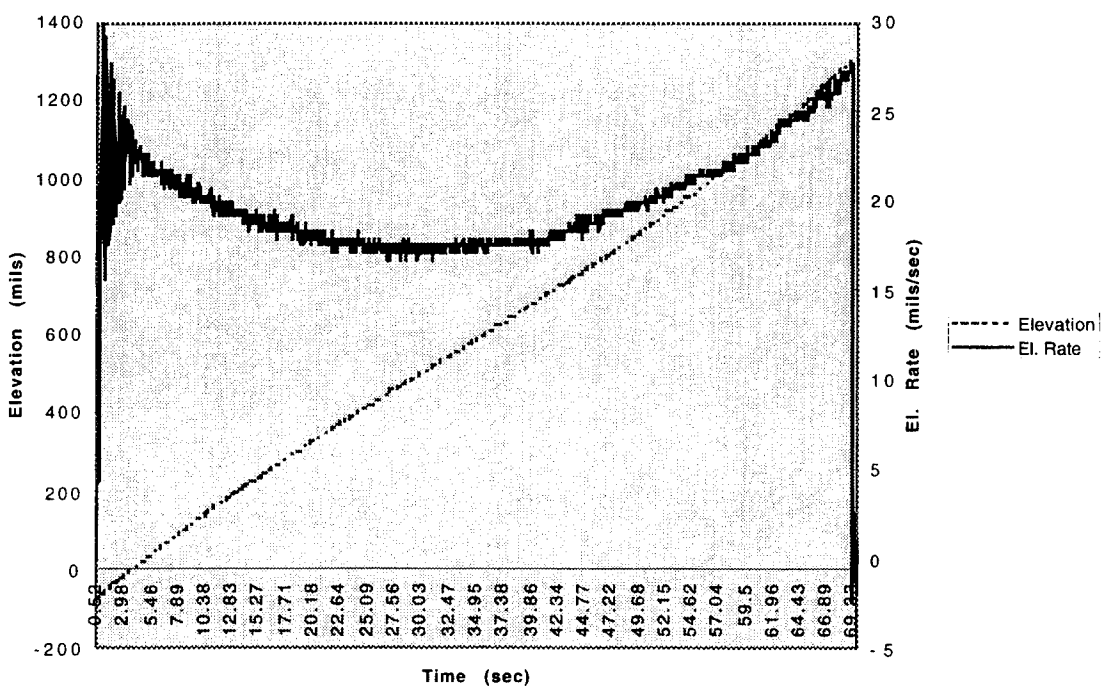
W1955FT 20 Degree Handle Actuation



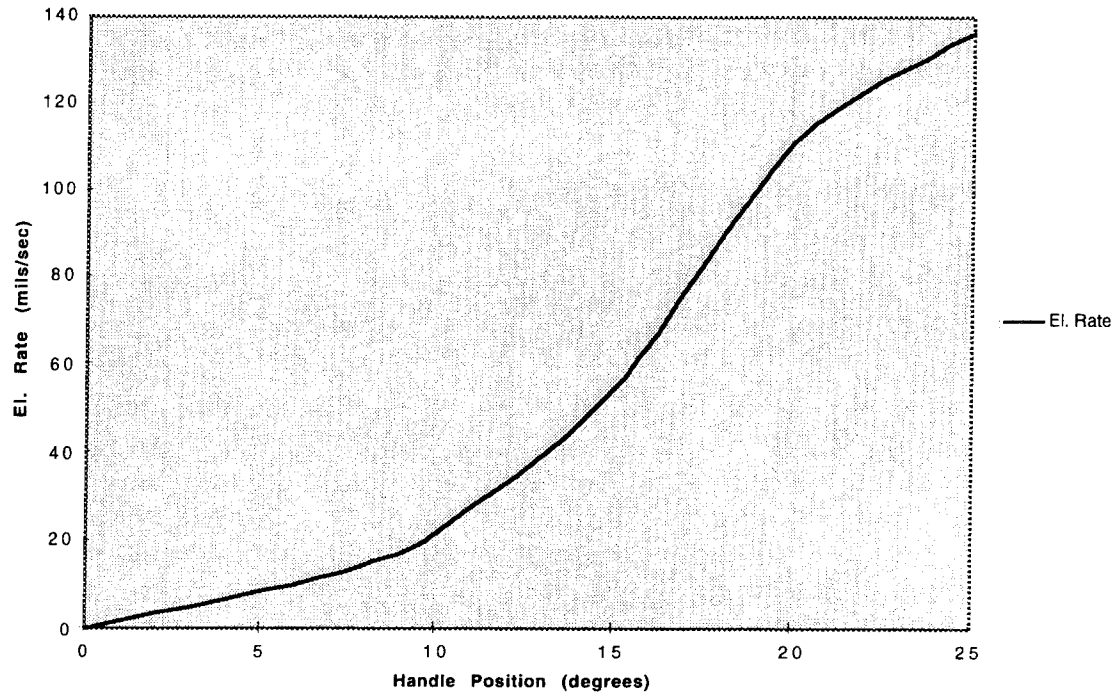
W1952FT 25 Degree Handle Actuation



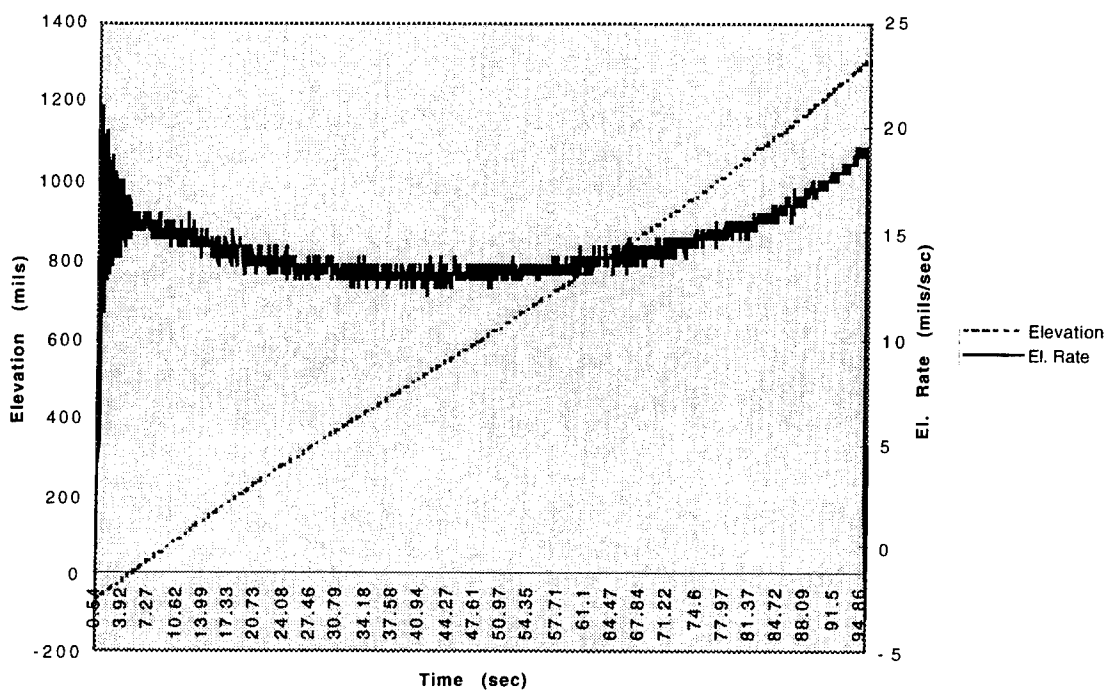
W1955FT Manual Handpump Elevation



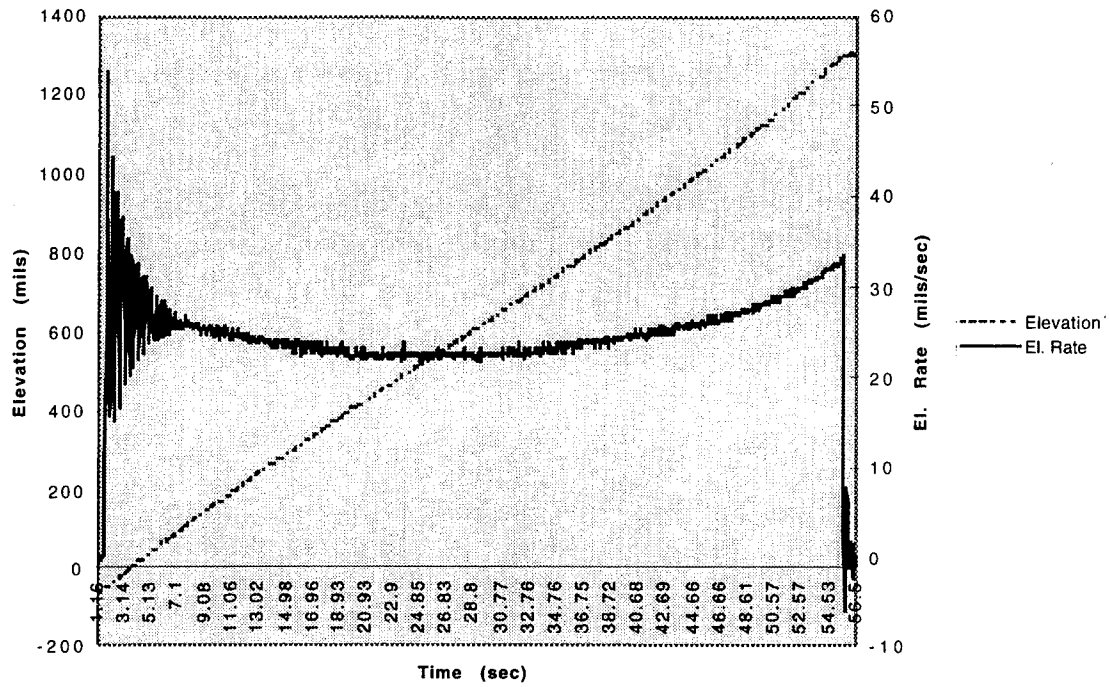
W1955FT El. Rate vs. Handle Position (533 mils)



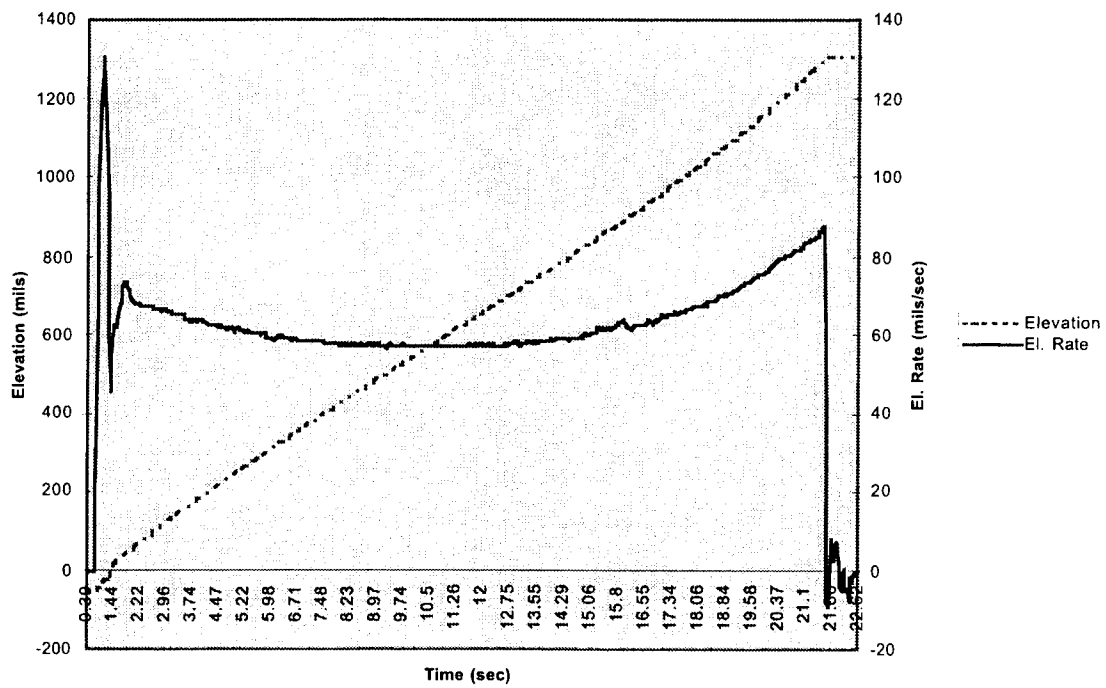
W1952FT 7.5 Degree Handle Actuation

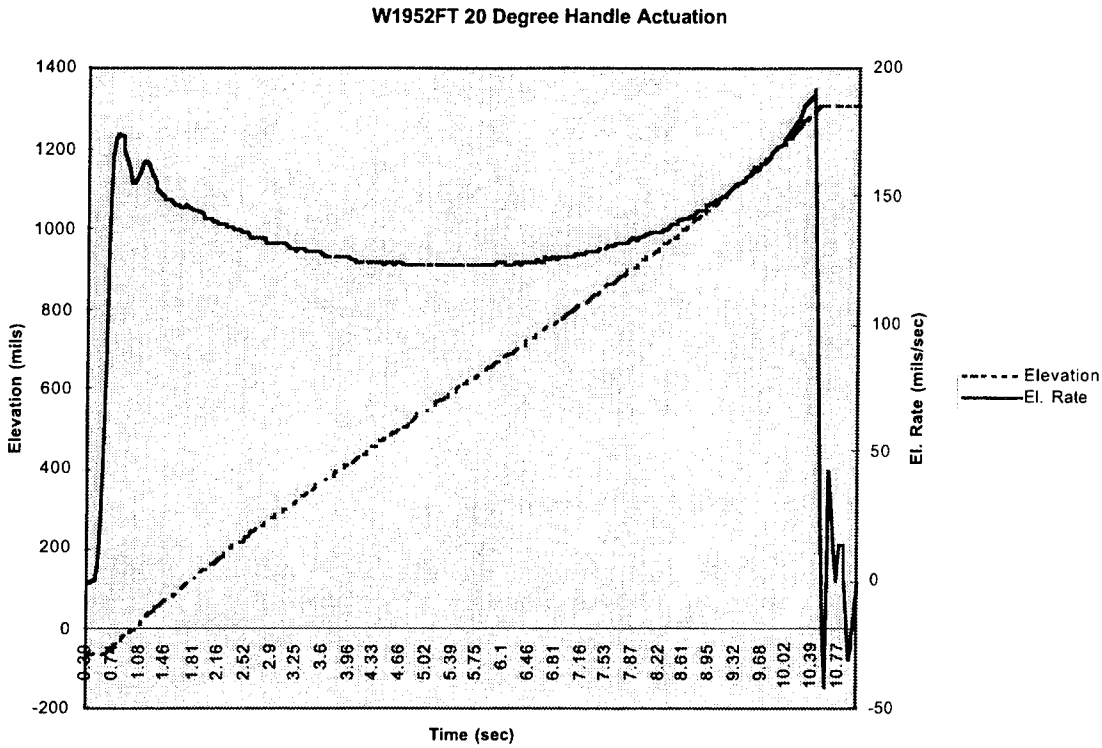


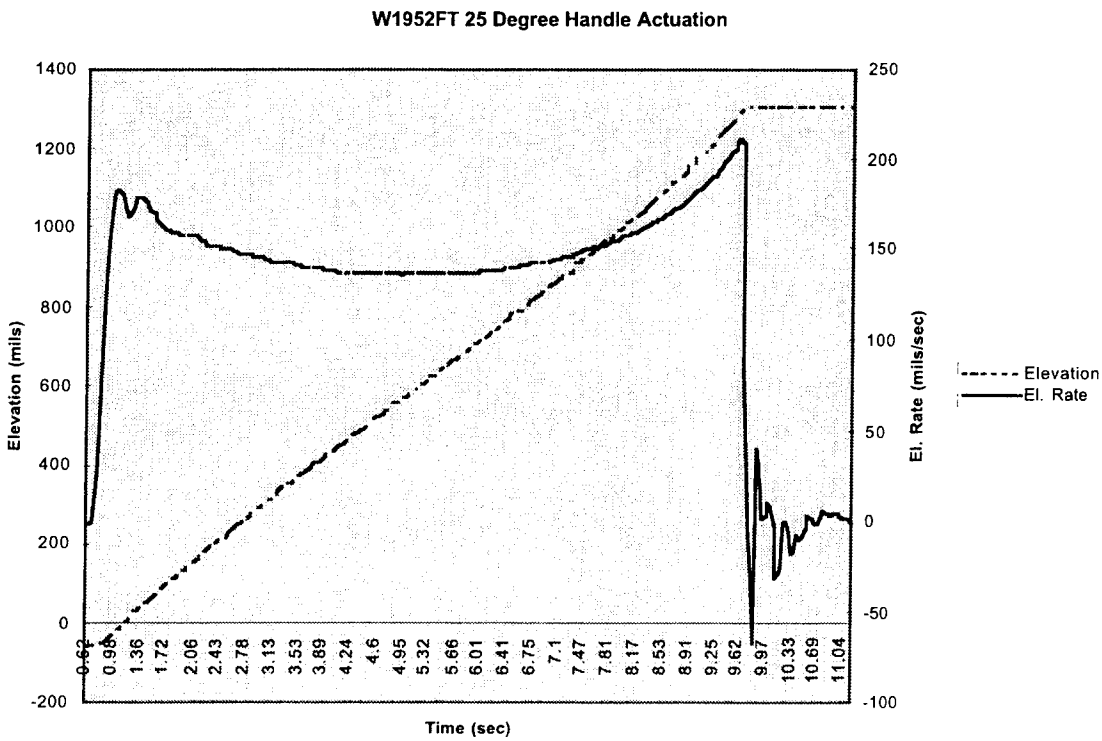
W1952FT 10 Degree Handle Actuation



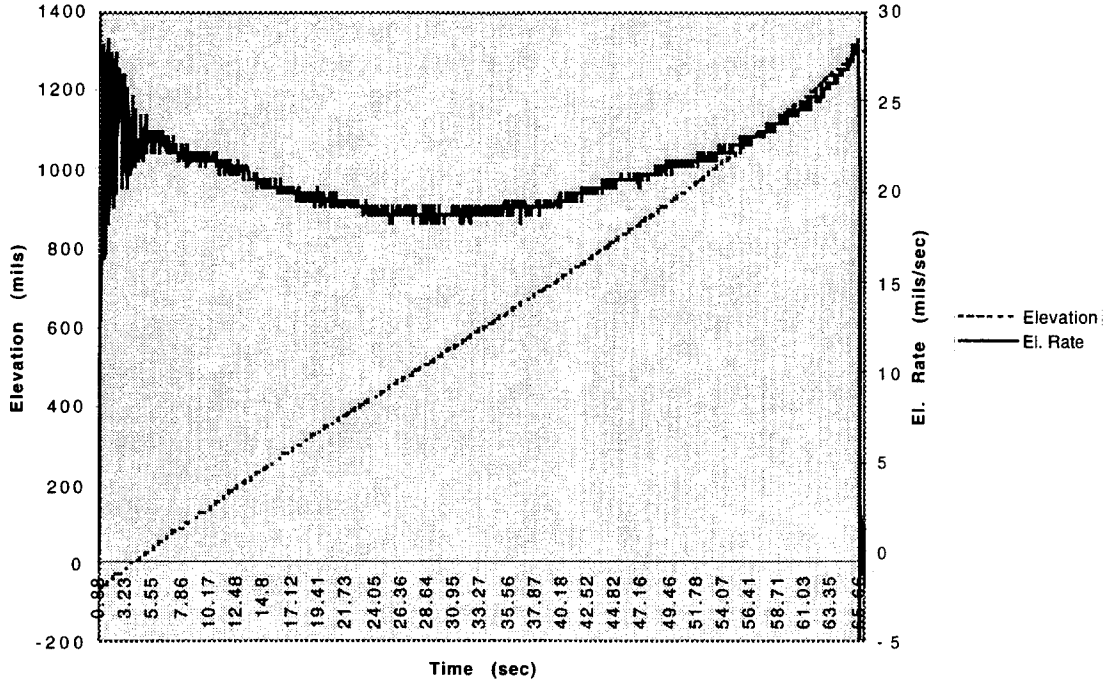
W1952FT 15 Degree Handle Actuation



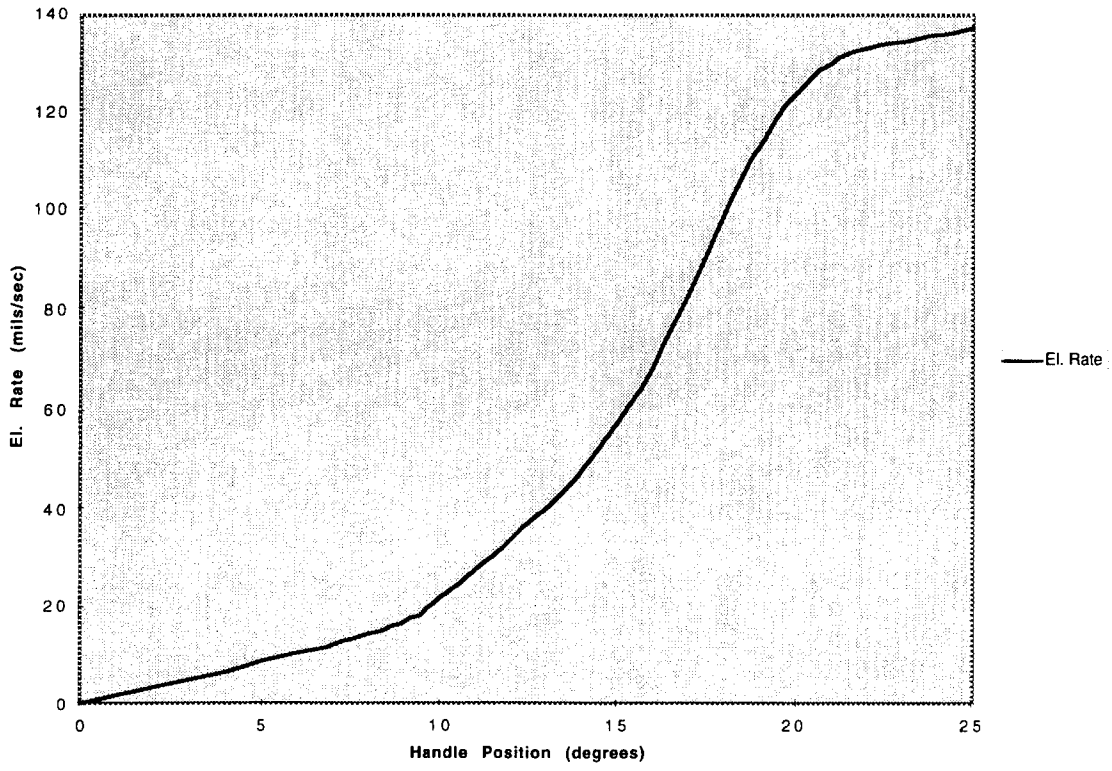

W1952FT 20 Degree Handle Actuation
Elevation (mils)
El. Rate (mils/sec)
Time (sec)
Elevation
El. Rate


W1952FT 25 Degree Handle Actuation
Elevation (mils)
El. Rate (mils/sec)
Time (sec)
Elevation
El. Rate

W1952FT Manual Handpump Elevation



W1952FT El. Rate vs. Handle Position (533 mils)



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